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REPORT OF THE COMMITTEE ON DYNAMO-ELECTRIC MACHINES.

[Continued from Vol. lxxv, page 303.]

THE INVESTIGATIONS OF THE SUB-COMMITTEE ON ELECTRICAL MEASUREMENTS.

By Profs. EDWIN J. HOUSTON and ELIHU THOMSON.

Now that the conversion of motive power into electricity, and the use of the latter for lighting, the deposition of metals, etc., are rapidly gaining in importance, it has become desirable that reliable data be obtained as to the efficiency of the various types of machines designed for producing electrical current from motive power.

In entering this comparatively new field of research, we have been met by peculiar difficulties, owing to conditions, that do not exist in the various forms of batteries used as sources of electrical power.

In many battery circuits a high external resistance may be employed, and the electromotive force remain comparatively constant, while in dynamo-electric machines, in which the reaction principle is employed, the introduction of a very high external resistance into the circuit must be necessarily attended by decided variations in the

electromotive force, due to changes in the intensity of the magnetic field in which the currents have their origin. Moreover, a considerable difficulty is experienced in the great variations in the behavior of these machines when the resistance of the arc, or that of the external work, is changed. Changes, due to loss of conductivity by heating, also take place in the machine itself.

The variations above mentioned are also attended by changes in the power required to drive the machine, and in the speed of running, which again react on the current generated.

There are certain normal conditions in the running of dynamo-electric machines designed for light, under which all measurements must be made, viz.:

1. The circuit must be closed, since, on opening, all electrical manifestations cease.

2. The circuit must be closed through an external resistance equal to that of the arc of the machine.

3. The arc taken as the standard must be the normal arc of the machine. This condition can only be fulfilled by noticing the behavior of the machine while running, as to the absence of sparks at the commutator, the heating of the machine, the regularity of action in the consumption of carbons in the lamp, etc.

4. The speed of the machine must be, as nearly as possible, constant.

5. The power required to maintain a given rate of speed must be, as nearly as possible, constant.

The machines submitted to us for determinations, were as follows, viz.:

1. Two machines of different size, and of somewhat different detailed construction, built according to the invention of Mr. C. F. Brush, and styled respectively in our report as A^1, the larger of the two machines, and A^2 the smaller.

2. Two machines known as the Wallace-Farmer machines, differing in size, and in minor details of construction, and designated respectively as B^1, the larger of the two, and B^2, the smaller. In the case of the machine B^1, the experiments were discontinued after the measurement of the resistances were made, insufficient power being at our disposal to maintain the machine at its proper rate of speed.

3. A Gramme machine of the ordinary construction.

All the above machines are constructed so that the whole current

traverses the coils of the field magnets, being single current machines, in which the reaction principle is employed. In the case of the machine designated A^2, the commutators are so arranged as to permit the use of two separate circuits when desired.

For the purpose of preserving a ready measure of the current produced by each machine, under normal conditions, a shunt was constructed by which an inconsiderable but definite proportion of the current was caused to traverse the coils of a galvanometer, thus giving with each machine, a convenient deflection which could at any time be reproduced. As the interposition of this shunt in the circuit did not appreciably increase its resistance, the normal conditions of running were preserved.

As indicating the preservation of normal conditions in any case, the speed of running and the resistances being the same as in any previous run, it was found that when there was an equal expenditure of power, as indicated by the dynamometer, the current produced, as indicated by the galvanometer, was in each case the same.

Certain of the machines experimented with heated considerably on a prolonged run; most of the tests, therefore, were made when the machines were as nearly as possible at about the temperature of the surrounding air. It is evident that no other standard could be well adopted, as under a prolonged run the temperature of the different parts of the machine would increase very unequally; and, moreover, it would be impossible to make any reliable measurements of the temperatures of many such parts.

In measuring the resistance of the machines, a Wheatstone's bridge, with a sliding contact, was used in connection with a delicate galvanometer and a suitable voltaic battery. In taking the resistances of the machines, several measurements were made with the armatures in different positions, and the mean of these measurements taken as the true resistance.

It was, of course, a matter of the greatest importance to obtain a value for the resistance of the arc in any case, since upon the relative values of this resistance, and that of the machine, the efficiency would in any given case, to a great extent, depend. In each case, the arc of which the resistance was to be taken, was that which was obtained when each machine was giving its average results as to steadiness of light and constancy of the galvanometer deflection.

The method adopted for the measurement of the arc was that of substitution, in which a resistance of German silver wire immersed

in water, was substituted for the arc, without altering any of the conditions of running. This substituted resistance was afterwards measured in the usual way, and gave, of course, the resistance of the arc. It could, therefore, when so desired, serve as a substitute for the arc. No other method of obtaining the arc resistance appeared applicable, since the constancy of the resistance of the arc required the passage of the entire current through the carbons.

It may be mentioned, as an interesting fact in this connection, that when the current flowing was great, the arc corresponding thereto had a much lower resistance than when the current was small. This fact is, of course, due to increased vaporization, consequent on increased temperature in the arc.

In determining the true arc resistance, the resistance of the electric lamp controlling the arc was measured separately, and deducted from the result obtained with the German silver wire substitute.

For ease of obtaining a resistance of German silver wire equal in any case to that of the arc, a simple rheostat was constructed, by winding, upon an open frame, such a length of wire as was judged to be in excess of the resistances of any of the arcs to be measured. By means of a sliding contact, successive lengths of the wire were added until the conditions as above stated were reproduced. The figure shows the arrangement of the rheostat. With this arrangement, no difficulty was experienced in reproducing the same conditions of normal running, as when the arc was used. The same conducting wires were used throughout these experiments. Being of heavy copper, their resistance was low, viz.: about ·016 ohm.

Having thus obtained the circuit resistances, we proceeded to determine the value of the current. Here the choice of a number of methods presented itself. We selected two methods, one based on the production of heat in a circuit of known resistance, and the other upon the comparison of a definite proportion of the current with that of a Daniell's battery.

In the application of the first method, eight litres of water, at a known temperature, were taken, and placed in a suitable non-conducting vessel. In this was immersed the German silver wire before mentioned, and the sliding contact so adjusted as to afford a resistance equal to that of the normal arc of the machine under con-

sideration. This was now introduced into the circuit of the machine. All these arrangements having been made, the temperature of the water was accurately obtained, by a delicate thermometer, reading readily to quarter degrees Fahrenheit. The current from the machine running under normal conditions was allowed to pass, for a definite time, through the calorimeter so provided. From the data thus obtained, after making the necessary corrections as to the weight of the water employed, the total heating effect in the arc and lamp, as given in Table II, was deduced.

Since the heat in various portions of an electrical circuit is directly proportional to the resistance of those portions, the total heat of the circuit was easily calculated, and is given in Table III, in English heat units. For ease of reference, the constant has been given for conversion of these units into the now commonly accepted units of heat.

Having thus obtained the heating effect, the electrical current is readily determined by the well known formula,

$$C = \sqrt{\frac{W h \times 772}{R t c}},$$

where $C =$ the veber current per ohm, W the weight of water in pounds, h the increase of temperature in degrees Fahr., 772 Joule's constant, R the resistance in ohms, t the time in seconds, and c the constant, ·737335, the equivalent in foot-pounds of one veber per per ohm per second. The currents so deduced for the different machines are given in Table IV.

The other method employed for obtaining the current, viz., the comparison of a definite portion thereof, with the current from a Daniell's battery, was as follows: a shunt was constructed, of which one division of the circuit was ·12 ohm, and the other 3000 ohms. In this latter division of the circuit was placed a low-resistance galvanometer, on which convenient deflections were obtained. This shunt being placed in the circuit of the machine, the galvanometer deflections were carefully noted. To the resistance afforded by the shunt, such additional resistance was added, as to make the whole equal to that of the normal arc of the machine. These substituted resistances were immersed in water, in order to maintain an equable temperature.

Three Daniell's cells were carefully set up and put in circuit with the same galvanometer used above, and with a set of standard resistance

coils. Resistances were unplugged sufficient to produce the same deflections as those noted with the shunt above mentioned. The shunt ratio, as nearly as could conveniently be obtained, was $\frac{1}{25000}$. Then the formula,

$$C = \frac{s\,n \times 1{\cdot}079}{R},$$

where C equals the veber current, s the reciprocal of the shunt ratio, n the number of cells employed, 1·079 the assumed normal value of the electromotive force of a Daniell's cell, and R the resistances in the circuit with the battery, gives at once the current. In comparison with the total resistances of the circuit, the internal resistance of the battery was so small as to be neglected.

The results obtained were as follows:

Name of Machine.	Shunt ratio.	Number of Daniell's cells.	Resistances unplugged.	Speed of Machine.
Large Brush, . .	$\frac{1}{25000}$	3	2710 ohms.	1340 rev.
Small Brush, . .	"	"	3700 "	1400 "
Wallace-Farmer, { .	"	"	8320 "	844 "
.	"	"	6980 "	1040 "
Gramme, ...	"	"	4800 "	800 "

The veber currents, as calculated from the above data, are given in Table IV.

From the results thus derived, the electromotive force was deduced by the general formula,

$$E = C \times R.$$

The electromotive force thus calculated will be found in Table IV.

Statements are frequently made, when speaking of certain dynamo-electric machines, that they are equal to a given number of Daniell's, or other well-known, battery cells. It is evident, however, that no such comparison can properly be made, since the electromotive force of a dynamo-electric machine, in which the reaction principle is employed, changes considerably with any change in the relative resistances of the circuit of which it forms a part, while that of any good form of battery, disregarding polarization, remains approximately constant. The internal resistance of dynamo-electric machines is, as a rule, very much lower than that of any ordinary series of battery

cells, as generally constructed, and, therefore, to obtain with a battery, conditions equivalent to those in a dynamo-electric machine, a sufficient number of cells in series would have to be employed to give the same electromotive force; while, at the same time, the size of the cells, or their number in multiple arc, would require to be such that the internal resistance should equal that of the machine.

Suppose, for example, that it be desired to replace the large Brush machine by a battery whose electromotive force and internal and external resistances are all equal to that of the machine, and that we adopt as a standard a Daniell's cell, of an internal resistance of, say, one ohm. Referring to Table IV, the electromotive force of this machine is about 39 volts, to produce which about 37 cells, in series, would be required; but, by Table II, the internal resistance of this machine is about ·49 ohm. To reduce the resistance of our standard cell to this figure, when 37 cells are employed in series, 76 cells, in multiple arc, would be required. Therefore, the total number of cells necessary to replace this machine would equal 37×76, or 2812 cells, working over the same external resistance. It must be borne in mind, however, that although the machine above-mentioned is equal to 2812 of the cells taken, that no other arrangement of these cells than that mentioned, viz., 76 in multiple arc, and 37 in series, could reproduce the same conditions, and, moreover, the external resistances must be the same. The same principles, applied to the other machines, would, when the internal resistance was great, require a large number of cells, but arranged in such a way as to be extremely wasteful, from by far the greater portion of the work being done in overcoming the resistance of the battery itself.

The true comparative measure of the efficiency of dynamo-electric machines as means for converting motive power into work derived from electrical currents, whether as light, heat, or chemical decomposition, is found by comparing the units of work consumed with the equivalent units of work appearing in the circuit external to the machine. In Table V, the comparative data are given. In the first column the dynamometer reading gives the total power consumed; from which are to be deducted the figures given in the second column, being the work expended in friction, and in overcoming the resistance of the air; although, of course, it must be borne in mind, that, that machine is the most economical in which, other things being equal, the resistance of the air and the friction, are the least. The third

column gives the total power expended in producing electrical effects, a portion only of which, however, appears in the effective circuit, the remainder being variously consumed in the production of local circuits in the different masses of metal composing the machines. This work eventually appears as heat, in the machine. Columns four, five and six give respectively the relative amounts of power variously appearing as heat in the arc, in the entire circuit, and as heat due to local circuits in the conducting masses of metal in the machine, irrespective of the wire. This latter consumption of force may be conveniently described as due to the *local action* of the machine, and is manifestly comparable to the well known local action of the voltaic battery, since in each case it not only acts to diminish the effective current produced, but also adds to the cost.

We desire to call attention to the fact, that in all the determinations conducted by us, we have been particularly careful to ensure a definite relation between the external and internal resistances in each case, a condition of paramount importance in the effective working of these machines. It is evident indeed, that no determinations made with an unknown or abnormal external resistance can be of any value, since the proportion of work done, in the several portions of an electrical circuit, depends upon, and varies with, the resistances they offer to its passage. If, therefore, in separate determinations with any particular machine, the resistance of that part of a circuit of which the work is measured be, in one instance large, in proportion to that of the remainder of the circuit, and in another small, the two measurements thus made would give widely different results, since in the case where a large resistance was interposed in this part of the circuit, the percentage of the total work appearing there would be greater than if the small resistance had been used.

When an attempt has been made to determine the efficiency of a single machine, or of the relative efficiency of a number of machines, by noting the quantity of gas evolved in a voltameter, or by the electrolysis of copper sulphate in a decomposing cell, when the resistance of the voltameter or decomposing cell did not represent the normal working resistance, it is manifest that the results cannot properly be taken as a measure of the actual efficiency.

In Table II it will be found that, in general, where the machine used had a high internal resistance, the arc resistance normal to it was also high, but they are not necessarily dependent upon each other.

TABLE II.—Resistances of Dynamo-Electric Machines.

From Determinations by Edwin J. Houston and Elihu Thomson.

NAME OF MACHINE.	Temperature in degrees F.	Resistances		Resistance of conducting Wire.	Resistance of Lamp, exclusive of Arc.	Corrected Resistances		Total resistance of the Circuit, Ohms.	REMARKS.
		Of Machine +conductor.	Of Arc +Lamp.			Of Machine —conductor.	Of Arc —Lamp.		
A^1, Large Brush, .	$73\frac{1}{2}$°	·485	·57	·016	·032	·483	·54	1 055	At beginning of run.
A^1, " " .	88	·495	·82	·016	·032	·493	·79	1·315	After running 25 min.
A^2, Small Brush, .	74	1·255	1·70	·016	·032	1·239	1·67	2·955	Arranged for low resist.
A^2, " " .	74	5·06		·016		5·044			" " high "
B^1, Large Wallace,	74	4·60	1·98	·016	·032	4·584	1·95	6·58	Machine cold.
B^1, " "	118	5·13							After 40 min. run.
B^2, Small Wallace,	74	4·96	2·87	·016	·1025	4·944	2·77	7·83	At 844 rev.
B^2, " "	74	4·96	3·24	·016	·1025	4·944	3·18	8·24	" 1000 rev.
Gramme, ...	68	1·685	1·35	·016	·1025	1·669	1·25	3·04	Arc not normal.
"	68	1·685	1·97	·016	·1025	1·669	1·87	3·66	Arc normal.

The arc resistance depends on the intensity of the current, the nature of the carbons, and on their distance apart. Other conditions being the same, the resistance of the arc is less when the current is great.

Since all the machines examined were built for lighting, it will readily be seen that, other things being equal, that machine is the most economical in which the work done in the arc bears a considerable proportion to that done in the whole circuit, and since, with any given current, the work is proportional to the resistance, we have in Table II the data for comparison in this regard. For example, in the second determination of A^1, the large Brush machine, the resistance of the arc constitutes considerably more than one-half the total resistance of the entire circuit, while in B^2, the small Wallace-Farmer machine, it constitutes somewhat more than one-third the total resistance. These relative resistances give, of course, only the proportion of the current generated, which is utilized in the arc as light and heat, the conditions of power consumed to produce the current not being there expressed.

During any continued run, the heating of the wire of the machine, either directly by the current, or indirectly from conduction from those parts of the machine heated by local action, as explained in a former part of this report, produces an increased resistance, and a consequent falling off in the effective current. Thus, in Table II, at the temperature of 73·5° Fahr., A^1, the large Brush machine, had a resistance of ·485 ohm, while at 88° Fahr., at the armature coils, it was ·495 ohm. These differences were still more marked in the case of B^1.

In A^2, the small Brush machine, it will be noticed that two separate values are given for the resistance of the machine. These correspond to different connections, viz., the resistance, 1·239 ohms, being the connection at the commutator for low resistance, the double conducting wires being coupled in multiple arc, while 5·044 ohms represent the resistance when the sections of the double conductor are coupled at the commutator in series.

Referring to Table III, the numbers given in the column headed "Heat in Arc and Lamp," are the measure of the total heating power in that portion of the circuit external to the machine. They do not, however, in the case of any machine, represent the energy which is available for the production of light, which depends also on the nature and the amount of the resistance over which it is expended.

TABLE III.—Thermic Effects of Dynamo-Electric Machines.

From Determinations by Edwin J. Houston and Elihu Thomson.

NAME OF MACHINE.	Galvanometer deflection with shunt.	Heating Effect in Arc and Lamp.			Resistance of Calorimeter equal to arc.	Heat in arc and lamp, in pounds H_2O, 1° F.	Total heat of the circuit, in lbs. H_2O, 1° F.	Heat per ohm, per second.	Speed of machine rev. per min.	Dynamometer reading, including friction.
		Lbs. H_2O.	Increase degrees Fahr.	Duration of run.						
A^1, Large Brush, . .	51½°	18·64	23·25	10	·82	43·338	69·49	·881	1340	107606
A^2, Small Brush, . .	34	18·63	9·09	5	1·70	33·87	58·87	·332	1200	117700
A^2, " " . .	37	18·63	18·66	8	1·70	43·45	75·57	·426	1400	124248
B^2, Small Wallace, . .	25½	18·63	11·50	12	2·87	17·85	48·70	·104	844	97068
B^2, " " . .	25½	18·63	4·92	6	2·87	15·28	41·69	·089	844	97068
B^2, " " . .	24½	18·64	10·75	10	3·28	20·04	50·34	·102	1040	128544
Gramme, ...	38	18·64	16·25	10	1·97	30·29	56·28	·256	800	60992

For conversion to new heat units — 1 lb. water, 1° F., = 259·185 grammes of water, 1° C.

For example, the heat in arc and lamp are practically the same in each of the Brush machines, if the measurement of the smaller of these machines be taken at the higher speed. The amount of light produced, however, is not the same in these two instances, being considerably greater in the case of the larger machine. The explanation of this apparent anomaly is undoubtedly to be found in the different resistances of the arcs in the two cases. In the large Brush machine the carbons are nearer together than when the small machine is used. This suggests the very plausible explanation, that the cause of the difference is to be attributed to the fact, that, although the total heating effect is equal in each case, when the large machine is used, the heat produced is evolved in a smaller space, and its temperature, and consequent light-giving power, thereby largely increased.

It would seem, indeed, that any future improvements made in the direction of obtaining an increased intensity of light from a given current, will be by concentrating the resistance normal to the arc in the most limited space practicable, thereby increasing the intensity of the heat, and, consequently, its attendant light.

It may be noted, in this connection, that in all the cases in which the resistance of the arc was low, the photometric intensity was high. This, indeed, might naturally be expected, since a great intensity of heat would, under existing conditions of the use of the arc, admit of increased vaporization, and consequent lowering of the resistance.

In the column headed "Total Heat of Circuit," are given the quantities of heat developed in the whole circuit, which numbers, compared with those in the preceding column, furnish us with the relative proportions of the work of the circuit, which appear in the arc and lamp.

The column headed "Heat per ohm per second," gives the relative work per ohm of resistance in each case, and these numbers, multiplied by the total resistance, give the total energy of the current expressed in heat units per second.

In Table IV are given the results of calculation and measurement, as to the electrical work of each machine. It is evident, to those acquainted with the principles of electrical science, that in the veber current and the electromotive force, we have the data for comparing the work of these machines with that of any other machine or battery, whether used for light, heat, electrolysis, or any other form of electrical work.

TABLE IV.—Current and Electromotive Force of Dynamo-Electric Machines.

From Determinations by Edwin J. Houston and Elihu Thomson.

NAME OF MACHINE.	Veber Current per ohm per sec.		Electromotive Force in Volts.		Per cent. of the work of current appearing in the arc.	Corresponding Dynamometric Values.	REMARKS.
	From heat developed.	By comparison with Daniell's batt.	Calc. from heat and resistance.	By comparison with Daniell's batt.			
A^1, Large Brush, . .	30·37	29·87	39·94	39·28	60·08	107606	Speed 1340 rev.
A^2, Small Brush, . .	18·63		55·05			117700	" 1200 "
A^2, " " . .	21·12	21·87	62·41	64·63	56·51	124248	" 1400 "
B^2, Small Wallace, .	10·42	9·73	81·59	76·19	35·38	97068	" 844 "
B^2, " " .	9·64		75·48				" 844 "
B^2, " " .	10·33	11·16	85·12	91·96	38·59	128544	" 1040 "
Gramme, ...	16·38	16·86	59·95	61·71	51·09	60992	" 800 "

As might be supposed, the values given in Table IV, of the veber current, approximate relatively to the photometric values, as will be seen from an examination of that part of the general report of the Committee relating to photometric measurements.

The values of the veber current, as deduced from the heat developed, and from the comparison with a Daniell's cell, do not exactly agree; nor could this have been expected, when the difficulty of minutely reproducing the conditions as to speed, resistance, etc., is considered.

By comparison of the electromotive force of the different machines, it appears that no definite unit seems to have been aimed at by all the makers as that best adapted to the production of light.

Table V is designed especially to permit a legitimate comparison of the relative efficiency of the machines, as well as their actual efficiency in converting motive power into current. The actual dynamometer reading, for which we are indebted to the sub-committee on the measurement of power, is given in the first column. On account of differences of construction, and differences in speed of running, the friction and resistance of the air vary greatly, being least with the Gramme, as might be expected, since the form of the revolving armature, and the speed of the machine, conduce to this result. This is, of course, a point greatly in favor of the Gramme machine.

That portion of the power expended available for producing current is given in the third column, being the remainder, after deducting the friction, as above mentioned; but this power is not in any case fully utilized in the normal circuit. This is found to be the case by comparing calculations of the total work of the circuit in foot-pounds, as given in the appropriate column, with the amount expended in producing such current.

For instance, in the case of A^1, the large Brush machine, the available force for producing current is 89656 F. P. per minute, of which only 53646 reappear as heat in the circuit. The balance is most probably expended in what we have termed *local action*, that is, the production of local currents in the various conducting masses of metal composing the machine. The amount thus expended in local action is given in the column designated "F. P. unaccounted for in the Circuit." A comparison of the figures in this column is decidedly in favor of the Gramme machine, it requiring the smallest proportion

TABLE V.—Effects of Dynamo-Electric Machines in Foot-Pounds per Minute.

From Determinations by Edwin J. Houston and Elihu Thomson.

NAME OF MACHINE.	Dynamometer reading. F. P. consumed.	Friction and resistance of air.	F. P. consumed, after deducting friction.	F. P. appearing in arc as heat.	F. P. appearing in whole circuit.	F. P. unaccounted for in the circuit.	Per cent. of power utilized in arc.	Per cent. of effect after deduct. friction.
A^1, Large Brush, .	107606	17950	89656	33457	53646	36010	31	37½
A^2, Small Brush, .	117700	12328	105372	26148	45448	59924	22	25
A^2, " " . .	124248	14976	109272	33543	58340	50932	27	31
B^2, Small Wallace, .	97068	7800	89268	13780	37596	51672	14	15½
B^2, " " .	128544	11072	117472	15469	38862	78610	12	13
Gramme, . .	60992	4512	56480	23384	43448	13032	38	41

For conversion into Gramme-metres — 1 foot-pound = 138 Gramme-metres, nearly.

of power expended, to be lost in local action. When, however, we consider that the current produced by the large Brush machine is nearly double that produced by the Gramme, the disproportion in the local action is not so great. The columns containing the percentages of "Power utilized in the Arc," and "Useful Effect after deducting Friction," need no special comment.

The determinations which we have made, as described in the foregoing part of this report, have enabled us to form the following opinions as to the comparative merits of the machines submitted to us for examination.

1. The Gramme machine is the most economical, considered as a means for converting motive power into electrical current, giving in the arc a useful result equal to 38 per cent., or to 41 per cent. after deducting friction and the resistance of the air. In this machine the loss of power in friction and local action is the least, the speed being comparatively low. If the resistance of the arc is kept normal, very little heating of the machine results, and there is an almost entire absence of sparks at the commutator.

2. The large Brush machine comes next in order of efficiency, giving in the arc a useful effect equal to 31 per cent. of the total power used, or 37½ per cent. after deducting friction. This machine is, indeed, but little inferior in this respect to the Gramme, having, however, the disadvantages of high speed, and a greater proportionate loss of power in friction, etc. This loss is nearly compensated by the advantage this machine possesses over the others of working with a high external compared with the internal, resistance, this also ensuring comparative absence of heating in the machine. This machine gave the most powerful current, and consequently the greatest light.

3. The small Brush machine stands third in efficiency, giving in the arc a useful result equal to 27 per cent., or 31 per cent. after deducting friction. Although somewhat inferior to the Gramme, it is, nevertheless, a machine admirably adapted to the production of intense currents, and has the advantage of being made to furnish currents of widely varying electromotive force. By suitably connecting the machine, as before described, the electromotive force may be increased to over 120 volts. It possesses, moreover, the advantage of division of the conductor into two circuits, a feature which, how-

ever, is also possessed by some forms of other machines. The simplicity and ease of repair of the commutator are also advantages. Again, this machine does not heat greatly.

4. The Wallace-Farmer machine does not return to the effective circuit as large a proportion of power as the other machines, although it uses, in electrical work, a large amount of power in a small space. The cause of its small economy is the expenditure of a large proportion of the power in the production of local action. By remedying this defect, a very admirable machine would be produced.

We regret that a machine of the Siemens type was not placed at our disposal, since whatever value our determinations may possess, would then have been increased by embodying data concerning a machine so widely and so favorably known, especially as the Siemens machine employs an armature differing in construction from that of any of the machines examined, wire only being revolved, a construction, which theoretically favors economy in working.

After careful consideration of all the facts embodied in the preceding reports, the Committee has unanimously concluded that the small Brush machine, though somewhat less economical than the Gramme machine, or the large Brush machine, for the general production of light and of electrical currents, is, of the various machines experimented with, the best adapted for the purposes of the Institute, chiefly for the following reasons:

1. It is admirably adapted to the production of currents of widely varying electromotive force, and produces a good light.

2. From the mechanical details of its construction, especially at the commutators, it possesses great ease of repair to the parts subject to wear.

The Committee therefore recommends that it be selected for purchase.

The Committee desires to express its thanks to Prof. H. W. Wiley, for the loan of the Gramme machine, to the Committee of the Central High School, to the Fales & Jenks Manufacturing Co., to Mr. J. W. Sutton, to Messrs. Wm. Sellers & Co., to Messrs. W. W.

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ROBERT E. ROGERS,
PLINY E. CHASE,
ROBERT BRIGGS,
EDWIN J. HOUSTON,
ELIHU THOMSON,
THEO. D. RAND,
WASHINGTON JONES,
SAMUEL SARTAIN,
J. B. KNIGHT, *Chairman.*

ERRATA.—In the table on p. 302, this vol., the weight of wire in the Gramme machine should be: on armature, 9½ lbs.; and on field-magnets, 57½ lbs.

THE TELEPHONE.

By BROWN AYRES.

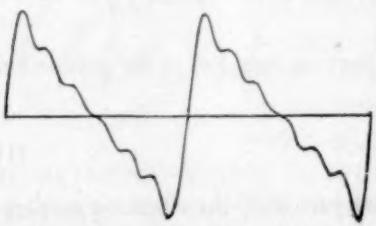
Probably no invention ever attracted more universal and interested attention than the telephone, and it is safe to say that none was ever more deserving of it, whether we regard the instrument in its intrinsic interest from a scientific standpoint, or whether we look at it in its purely practical bearing. The public, by a legion of newspaper articles and public lectures, has become moderately familiar with the general construction and operation of the instrument, but no one seems as yet to have considered it in its theoretic aspects, nor to have given to the public many very remarkable facts that can hardly have failed to have attracted the attention of any one who has worked to any considerable extent with the instrument. An outline of this theory, and a few of these facts, it is the purpose of the writer to present in the present paper, with the hope that it may at least stimulate others more fully prepared for the task to give the subject more thorough attention.

The complete understanding of the action of the telephone, covering, as it does, some of the most refined portions of Dynamics, would require mathematical processes of the greatest complexity and difficulty; but a clear understanding of the general principles of the

operation of the instrument, with enough of the quantitative relations involved to give us definite ideas in regard to its action, need not be inconsistent with a limited knowledge of the higher mathematical processes.

In attempting to form a conception of the action of the telephone, we must keep constantly before our minds the mutual relations of pitch, intensity, and quality in the sensations of sound, and their relations to the corresponding amounts of energy involved in the various transformations through which the energy of the sound wave passes between its initial and final states as kinetic energy of atmospheric vibration. We may, to give breadth to our view of the subject, regard the instrument in a generalized form. As such, we shall find that it consists of three essential parts: Firstly, the mechanism which receives the energy of the vibrating air, *e. g.*, the plate; secondly, the mechanism for transforming the energy of sound motion so received into an equivalent of electric and other energy, or for regulating the development of electric energy in an external source, and lastly, the mechanism for reconverting the electric energy into aerial undulations. I have pictured the instrument thus in its generality, because in special points the various telephones differ, and the present method of construction can hardly be expected to be rigorously adhered to.

FIG. 1.



The requirement for an articulating telephone is that the working margin of the electric current and the action of the mechanism shall be so related that the sound given forth at the distant end of the line shall be in relative pitch, intensity and quality, an accurate reproduction of the sound initially produced. In all forms of telephone yet devised, as we shall directly see, the strength of the transmitted current is in direct proportion to the kinetic energy of an air particle engaged in the production of a given sound, and is independent of the pitch; so that for the purposes of this paper we may say that the requirements of an articulating telephone are that at any moment the working margin of current strength shall be directly proportional to the loudness of the sound (physically considered) and independent of its pitch. To convey a more concrete conception of

this, we may draw a curve (Fig. 1), whose ordinates will represent intensities of sound, while the abscissæ will represent periods of time. Any such curve, if it be harmonic in its character, may represent a musical sound. Now the requirement of a speaking telephone is that this same curve should represent the varying current strengths if the ordinates be currents while the abscissæ are times, as before.

These conditions are fulfilled by several different instruments to a greater or less degree of approximation. The various telephones yet devised may be classified as follows:

Class I. Telephones by induced currents (produced by the relative motion of a conductor and magnet).

(*a*). Those in which the magnet moves relatively to the conductor.

(*b*). Those in which the conductor moves relatively to the magnet.

(*c*). Those in which both move simultaneously.

Class II. Telephones by *variation* in a Voltaic current. A variation, according to Ohm's law $\left(I = \frac{E}{R}\right)$, can only be produced by varying E or R. Hence of this class there are:

(*a*). Those that vary the electromotive force.

(*b*). Those that vary the resistance of the circuit.

Class III. The Electrostatic telephone of the writer, to be directly described.

The equation of the motion of a particle engaged in the production of any simple tone,[1] is

$$y = a \sin\left(\frac{2\pi t}{\tau} + \alpha\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where a and τ are the amplitude and period of the vibration respectively, and α is a constant depending on the time that has elapsed from the commencement of the motion until the moment we begin to reckon. The variable velocity of the particle is

$$\frac{dy}{dt} = a. \cos\left(\frac{2\pi t}{\tau} + \alpha\right)\frac{2\pi}{\tau}. \quad . \quad . \quad . \quad . \quad (2)$$

For our purpose a sufficiently exact expression for the kinetic energy of the vibrating particle while producing any note can be reached

[1] Donkin, "Acoustics," p. 47.

as follows: The total energy of the vibration at any time consists of two parts, kinetic and potential, the sum of which is constant. The whole of it will be manifested as kinetic energy as the particle passes its point of equilibrium. At this point $y = 0$, hence

$$\sin\left(\frac{2\pi t}{\tau} + \alpha\right) = 0,$$

$$\therefore \cos\left(\frac{2\pi t}{\tau} + \alpha\right) = \pm 1,$$

$$\text{and } \frac{d\,y}{d\,t} = \pm \frac{2\pi}{\tau} a.$$

But the kinetic energy is $\frac{1}{2} m v^2$

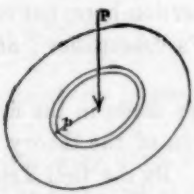
$$\therefore \tfrac{1}{2} m v^2 = 2 m \frac{\pi^2 a^2}{\tau^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Then the whole force exerted by any collection of particles vibrating synchronously will be

$$\Sigma \frac{m v^2}{2} = \Sigma \frac{2 m \pi^2 a^2}{\tau^2}.$$

From which we see that with a given mass of vibrating particles the kinetic energy varies as the square of the amplitude divided by the square of the period; or, what is the same thing, as the square of the product of the amplitude by the number of vibrations in a unit of time.

Fig. 2.



In all telephones yet devised, the aerial undulations are received on a flat disc of thin elastic substance—such as mica, rubber, or iron—and hence this portion of the theory is common to all forms. The complete investigation of the relations between the applied forces and the resultant action of the plate in the telephone forms one of the most complex dynamical problems in the whole range of science, but an expression for the relation between the variables, sufficiently exact for our purpose, may be reached in the following manner. Let us treat the problem as one of shearing stress, Fig. 2:

Let P = applied force,
Δ = deflection of plate,
ρ = variable radius,
t = thickness of plate,
e = coefficient of transverse elasticity.

Then[i] according to the law of shearing stress,

$$P = 2\pi t e \rho \cdot \frac{d\Delta}{d\rho}; \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

whence we have

$$d\Delta = \frac{P}{2\pi t e} \cdot \frac{d\rho}{\rho};$$

and integrating between the limits r, the radius of the plate, and r_1, the radius of the area on which the force is applied, we have

$$\Delta = \frac{P}{2\pi t e} \cdot \log \frac{r}{r_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

From equations (3) and (5) we see that within the elastic limit of the plate, the deflection will be proportional to the kinetic energy of the sound wave.

"It can be shown that no forced vibration can have any harmonic component of a period which does not exist amongst the periods of the harmonic component of the imposed motions or forces."[ii] The plate then must follow every motion of the alternately condensed and rarefied air particles. Though I have only given an expression in equation (3) for the kinetic energy of a single note, it will readily be perceived that in the case of a complex motion, at any given moment, the energy will be represented by that expression. The discussion of the general equation would be too lengthy for insertion here, but can easily be found by those interested. (See Donkin's "Acoustics" and Rayleigh's "Theory of Sound.")

The theory of the three divisions which I have made in the first class of telephones, is the same; hence an exposition of the theory of the Bell Telephone will answer for the other two. By the Bell Telephone we will understand that arrangement of a vibrating plate of magnetic matter before the pole or poles of a magnet—temporary or permanent—around which pole or poles wire is wound after the manner of an electro-magnet. In a general way the explanation of its action could be given somewhat in this wise: The motion of the plate, by disturbing the distribution of the magnetic field, causes a motion of the magnetic lines of force, which, cutting across the wires of the helix, cause a current to be induced in these wires. This current, passing over the line, causes a variation in the force with which the

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[i] Wood, "Resistance of Materials," p. 215.

[ii] Donkin, "Acoustics," p. 89.

plate at the further end is attracted, and the variation imparts to the plate a motion depending on the varying strengths of the incoming current. The motion of the lines of force can be readily observed if we cover the poles of a rather powerful horse-shoe magnet with not too fine iron filings, and move the armature to and fro before the poles. It can also be readily shown by means of the floating magnetic needles described by Prof. A. M. Mayer, in the *Am. Jour. Sci. and Arts*, for April, 1878.

The theory of the action is as follows:[1]

If m be the magnet strength, and the induced magnetism of the plate, which, of course, is a function of m, be $q\,m$, where q is some constant, then the attractive force between them will be

$$\frac{q\,m\,.\,m}{p^2} = \frac{q\,m^2}{p^2},$$

where p is the distance between the poles of the magnet and plate. Now if the plate be moved to any new position, p_2, from its initial position, p_1, work will be done by or against the attractive force.

$$\text{This work} \quad = q\,m^2 \int_{p_2}^{p_1} \frac{dp}{p^2} = q\left(\frac{m^2}{p_2} - \frac{m^2}{p_1}\right);$$

but $\frac{q\,m^2}{p_1}$, $\frac{q\,m^2}{p_2}$, are the values for the potential at the positions p_1, p_2, respectively; hence

$$\text{Work} = q\,(V_2 - V_1);$$

or the work done will be manifested by a variation in the potential.

The potential at the time will evidently depend on the state of the magnetic field.

$$V = f(\gamma) = M\gamma.$$

But on the difference of potential at any two instants will depend the electromotive force of our induced current:

$$V_2 - V_1 = M_2\gamma_2 - M_1\gamma_1 = E = IR,$$

$$\text{hence} \quad I = \frac{V_2 - V_1}{R} = \frac{M_2\gamma_2 - M_1\gamma_1}{R}, \quad . \quad . \quad . \quad (6)$$

or, the strength of the induced current will be equal to the difference

[1] For a more complete discussion see Cumming, "Theory of Electricity," p. 210; Maxwell, "Electricity and Magnetism," Vol. II, p. 176.

in the potential of the system at two given instants, divided by the resistance of the circuit. The quantity $M\gamma$ can be interpreted as the number of lines of force passing through the coil, M depending for its value on the position of the coil and plate with reference to the magnet, and γ being the number of lines of force in unit area of the equipotential surface at unit's distance from the pole at the instant that the quantity $M\gamma$ is observed. It will readily be seen that γ depends on the magnetic strength, while M depends on the arrangement and adjustment of the instrument as well as the intensity of the sound wave impinging on the plate. With any given arrangement of magnet, coil and plate, any change in $M\gamma$ will be dependent on the position of the plate, that being the only movable portion of the instrument. Hence if A be the position of the plate at any instant

$$M\gamma = f(A) = kA$$

and

$$M_2\gamma_2 - M_1\gamma_1 = k(A_2 - A_1), \quad . \quad . \quad . \quad (7)$$

or, the variation in the potential is proportional to the amplitude of vibration, hence the strength of the induced current will be proportional to the amplitude of vibration, and therefore proportional to the kinetic energy of the sound wave.

This current traversing the wire will cause a variation in the magnetic strength of the distant telephone, either by augmenting or diminishing it according to the direction of the current. The variation will be sensibly proportional to the strength of current, as will be shown later. Hence a force will be exerted on the distant plate proportional to the kinetic energy of the initial wave of sound. The intensity of the emitted sound will therefore, at any instant, be in direct proportion to the initial sound. It will be observed that in the above discussion no notice is taken of the pitch of the note, whatever it might be, except where it enters the expression for the kinetic energy of the initial sound wave; but it will readily be seen that whatever be the motion, if the distant plate is at every moment attracted with a force varying as the motion of the first plate, all the conditions for the transmission of sounds, however complex, are fulfilled. It remains for us to examine what are the requirements in the receiver that its plate may have a force exerted on it directly as the strength of the incoming currents.

Let m be the magnetism of the magnet, which, if produced by a current, will be directly proportional to it, $= a\gamma$.

Let K = induced magnetism of the plate $= f(m) = q(m)$.

Assume the initial distance of the centre of magnetism of the plate from that of the magnet $= p$. Then the attractive force $F = \frac{q\,m\,.\,m}{p^2} = \frac{q\,m^2}{p^2} = \frac{q\,a^2\,\gamma^2}{p^2}$; or the attraction is as the square of the current, as was demonstrated by Joule.

Suppose m to undergo any variation $\overline{\Delta\gamma}$, due to a variation in γ, then $F_1 = \frac{q\,a^2}{p^2}(\gamma + \overline{\Delta\gamma})^2 = \frac{q\,a^2}{p^2}(\gamma^2 + 2\gamma\,\overline{\Delta\gamma} + \overline{\Delta\gamma}^2)$.

hence, $\overline{\Delta F} = \frac{q\,a^2}{p^2}(2\gamma\,\overline{\Delta\gamma} + \overline{\Delta\gamma}^2)$.

If $\overline{\Delta\gamma}$ be very small, $\overline{\Delta\gamma}^2$ can be neglected without appreciable error, in which case

$$\overline{\Delta F} = \frac{2\gamma\,q\,a^2}{p^2}\,\overline{\Delta\gamma}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

From which we conclude that while the total strength is proportional to γ^2, the variation, if small, is proportional to $\Delta\gamma$; or, in other words, if the magnet is entirely magnetized and demagnetized by the incoming currents, the attractive force will be proportional to the square of the current; while if it be a permanent magnet, whose strength is varied, it will be proportional to the current. But if $\Delta\gamma$ be large, so that $\overline{\Delta\gamma}^2$ will have an appreciable value, the force will be augmented by the term $\overline{\Delta\gamma}^2$. Now in an articulating telephone, in order that the relative loudness of the component tones of a sound be preserved, the attractive force must vary as the current. Hence, for the receiver of an articulating telephone, a permanent magnet must be used; and, in order that $\Delta\gamma$ shall be sufficiently small, the permanent magnet should be as near saturation as possible. Hence loudness, arising from large margin of attractive force, will be fatal to perfection of articulation. In the Bell telephone, these requirements are beautifully fulfilled by the use of the same instrument as sender and receiver. This result also explains to us the imperfect working of the original form of Bell's instrument—with the electro-magnet. The magnet was too far from saturation by the constant current; hence the attractions more readily followed the law of Joule, than that of simple proportion, and the articulation was correspondingly imperfect.

The second class of articulating telephones consists of those which operate by a variation in the strength of a voltaic current. The strength of a current is, by Ohm's law,

$$I = \frac{E}{R};$$

hence, any variation in I must be caused by a variation in either E or R. We know of no method by which the electromotive force of a battery can be varied continuously; and since a discontinuous variation could hardly be made so gradual as to produce waves in the current capable of carrying the more delicate shades of quality, we are forced, for the present, to regard that telephone which varies the electromotive force to be possible only in theory. The Voltaic telephones, then, reduce to one class—those which vary the resistance of the circuit. A type of this form is what has been called the "Hydro-electric Telephone," described by Prof. Bell, in his paper read before the American Academy of Arts and Sciences, in May, 1876. This consists of a membrane, to which is attached a platinum wire dipping into water or other highly resisting liquid. The motion of the plate to and fro causes the wire to be more or less submerged in the liquid, and hence the resistance, between it and a wire projecting upward from the bottom of the containing vessel, is varied. If v be the resistance of the liquid between the extremities of the wires, R the external resistance, and E the electromotive force in circuit, then

$$I = \frac{E}{R + v}.$$

Let the plate vibrate so that the extreme values of the resistances of the liquid are v_1 and v_2, then

$$\Delta I = \frac{E}{R + v_1} - \frac{E}{R + v_2} = \frac{E(v_2 - v_1)}{R^2 + R(v_1 + v_2) + v_1 v_2}.$$

Now if R is small, compared with v, we may, to reach an approximate solution, neglect R; then

$$\Delta I = E\left(\frac{1}{v_1} - \frac{1}{v_2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

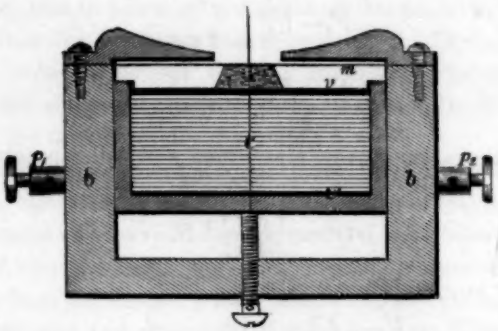
or the variation in current strength, for that amplitude of vibration will be proportional to the variation in conductivity of the circuit. To reach this result we have been forced to consider $R = 0$. But this can never be the case in a practicable arrangement; but the smaller is the internal resistance of the battery and conducting wires,

and the larger the value of v_1, the nearer will the instrument approach to theoretical exactness.

In the form of instrument devised by Mr. T. A. Edison, where advantage is taken of his discovery of the variation, in resistance, of graphite or lampblack under pressure, the current is passed through the primary of an induction coil, while the secondary goes to line, and the current induced by variation in strength of the primary is utilized for actual transmission to line. If the resistance of the plumbago varies inversely as the pressure, then this instrument has the same difficulty to contend with as the "Hydro-Electric Telephone," and in the same degree.

The third class is represented, at present, so far as I know, by one instrument, the "Electrostatic Telephone," of the writer, Fig. 3.

Fig. 3.



This consists simply of an insulating box of wood or rubber, b, in which is placed a small condenser, c, the sides of which are connected by binding posts, p_1, p_2. This condenser is constructed of tinfoil, as usual, insulated by discs of thin sheet rubber, such as is used by dentists. On either end of the condenser is placed a thin piece of vulcanite, v, v_1, the upper one of which is attached to a piece of cork, k, which bears against the ferrotype or mica plate, m, while the lower rests on a screw, s, by means of which the instrument can be adjusted. One side of the condenser is kept at a nearly constant potential by means of a large number of small cells, while the other side is connected to line. The vibrating plate which bears on the condenser, by its motion, increases and diminishes the pressure, and hence the distance between the leaves. The principle of operation is as follows:

The capacity of the condenser varies inversely as the distance between the plates, and when the capacity is varied by the varying distance, of the leaves apart, a current is set up momentarily in the line, which depends for its direction on whether the condenser is under- or super-saturated for that value of its capacity. The general theory will be understood from the following. For convenience, we may consider any two contiguous sheets. Since the lines of force between the sheets cut them at right angles, the value of the force does not vary with distance, and since the electrostatic force is measured by the rate of change of potential, we have:

$$F = \frac{V_1 - V_2}{t},$$

where t is the distance between the plates. But the force near any electrified surface is $4\pi\rho$ where ρ is the density,

$$\therefore \quad \frac{V_1 - V_2}{t} = 4\pi\rho.$$

Hence,
$$\rho = \frac{V_1 - V_2}{4\pi t}.$$

If S be the area of the plate then ρS will represent the total charge.

$$\therefore \quad Q = \frac{V_1 - V_2}{4\pi t} S.$$

Hence for any variation in Q,

$$\Delta Q = \frac{V_1 - V_2}{4\pi} S\left(\frac{1}{t_0} - \frac{1}{t_1}\right) \quad . \quad . \quad . \quad . \quad (10)$$

or the variation in charge will be proportional to the change in *thinness* of the dielectric, since the reciprocal of the distance between the plates may be called the thinness. This thinness may, within the small limits with which we have to deal, be considered as proportional to the applied force. Then the variation in thinness will be proportional to the amplitude of vibration of the plate. Experiments made thus far with this instrument are encouraging, though its interest is more purely scientific than practical.

We have now examined the theory of a typical instrument of each class, and have found in each case, with varying degrees of approximation: (1.) That the amplitude of vibration of the plate was proportional to the kinetic energy of the sound wave. (2.) That the current on the line was proportional to the amplitude of vibration of

the plate. (3.) Assuming the attractive effect of the current as directly proportional to it, the amplitude of vibration of the receiving plate is proportional to the strength of the current. (4.) That the kinetic energy of the sound emitted by the receiving plate is proportional to the amplitude of vibration of that plate, and hence the kinetic energy of the sound emitted is directly proportional to the kinetic energy of the initial sound. No time functions enter into any of equations (6), (8), and (10). Hence the action in every case is independent of the pitch of the note.

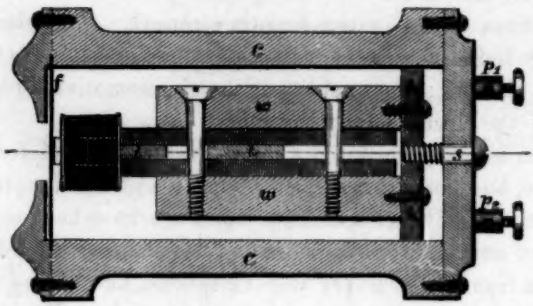
In equation (6) we see that the current depends on the change in $M\gamma$. As we have before remarked, this quantity may be considered as expressing the number of lines of force which pass through the conductor at any moment. Hence, to increase the current, the conductor should be so placed as to cut the greatest possible number of lines of force, and to allow of the greatest variation in the number of cutting lines for any given magnet strength. The electromotive force of the induced current will be proportional to the number of windings in the coil; the quantity to the electromotive force and conductivity of the circuit jointly, by Ohm's law.

The writer has experimented a great deal with the different forms of telephone, but more from a scientific than a practical point of view. Still in the course of his experiments some facts have been reached that are worthy of notice. He has devised a form of instrument differing in construction from the ordinary Bell Telephone, and having the advantage of greater ease and cheapness of manufacture. This instrument has been used by many scientific men who have visited the Stevens Institute, with the nearly unanimous opinion that it compared very favorably with the best yet constructed.

A sectional view of this instrument is shown in Fig. 4. The wooden case c, $4\frac{1}{4}$ inches in length by $2\frac{3}{4}$ in diameter, is, in the instrument made by the writer, of mahogany. Through this cylindrical block is bored a hole, 2 inches in diameter. Into this is fitted snugly the arrangement of magnets and coils tight enough to prevent its rattling about, but not so tight as to prevent its adjustment by means of the screw S. Two horseshoe magnets are used; they are 3 inches long and can be bought at any toy store at a cost of about fifteen cents apiece. A compound magnet is formed by superposing them, like pole over like, having a piece of wood T, $\frac{1}{8}$ inch in thickness, between them. A small piece of round iron or iron wire I, $\frac{3}{16}$ inch in

diameter and $1\frac{1}{4}$ inches in length, is filed flat on two opposite sides to within about $\frac{5}{8}$ inch of the end—somewhat over half. One of the pieces is placed between the superposed like poles, and the whole is held tightly together by means of two screws passing through and into two pieces of wood *w*, *w*. On the ends of *w* is screwed a strip of brass, *b*, which, by means of a screw thread in its centre, allows the whole arrangement to be moved in and out by the screw *S*. On the pieces of round iron *i*, are slipped bobbins (which I have made of postal card, boxwood, or hard rubber), whose dimensions are: length, $\frac{9}{16}$ inch, diameter, $\frac{1}{2}$ inch, and core just large enough to fit snugly on *i*. They are wound with No. 38 wire, or for short lines coarser wire can be used. Connections are made in the ordinary way to binding posts p_1, p_2, and a disc of thin ferrotype, *f*, is placed over the end,

FIG 4.



and the magnets brought as near as possible without touching when the plate vibrates. The mouthpiece is like that of any ordinary telephone. One great advantage of this form is the ease with which a strong magnet can be made, and strength of magnet is an essential in the telephone. My instruments have a resistance of about 80 ohms, and I have worked them very satisfactorily on actual wires up to 75 miles and with resistances much higher. There is considerable choice in the ferrotype plates one meets with; the best that I have found is an imported article, of a maroon color, and very thinly coated with varnish. The ordinary black American plates do very well, but the varnish is rather thick and they are not as satisfactory as the French. Of course the dimensions can be varied at pleasure, but the plate should not depart far from the size given, for if so, the fundamental tone of the plate will interfere with distinctness of articulation.

The writer has also experimented to some extent with a telephone which is a type of the second division of the first class of telephones. Two horseshoe magnets were placed about ¼ inch apart, with the opposite poles facing each other, and a circular coil of such a size as to move easily between them, and whose diameter was such that the upper portion was between the upper poles of the two magnets, while the lower was between the lower poles. This coil was attached directly to a mica membrane, and when sounds were uttered before the membrane the coil was thrown into vibration in the magnetic field, and the motion of the coil across the lines of force induced a current in the coil. Very fair results were obtained with this arrangement. This was also combined with the regular Bell telephone (Fig. 4), by attaching the coils to the ferrotype plate and allowing them to vibrate to and fro on the round iron as a piston. In this case the coil was pushed across the lines of force, at the same time that the lines of force were drawn across the coil. The articulation of this arrangement was the best that I have yet heard on any telephone, though in my experiment it was not so loud as the regular form alone, probably owing to there being a want of sufficient freedom of motion in the coils, thus damping the vibration.

In the experiments made with the electrostatic telephone, I used some 200 cells, of small test tube battery of simple zinc and copper plates in dilute sulphuric acid. The instrument had a capacity of about $\frac{1}{10}$ microfarad. While the results reached were not great enough to warrant more extensive investigation, they were sufficient to show that we had here a new means by which articulate and other complex sounds could be conveyed.

While experimenting on a wire of the Virginia Telegraph Co., the writer had occasion to notice more particularly a very curious fact which from previous experiments he had suspected before, that is, that the telephone seems to work more satisfactorily on a leaky line than on one perfectly insulated. His experiments were made on four wires. No. 1 was a wire of the Western Union Telegraph Co., from Staunton to Charlottesville, Va., a distance of 40 miles. No. 2, a wire of the same company, from Staunton to Covington, Va., a distance of 70 miles. No. 3, wire of the Virginia Telegraph Co., from Staunton to Harrisonburg, a distance of 25 miles, and No. 4, one of the Baltimore and Ohio R. R., between the same points, 25 miles. On Nos. 1, 2 and 4, which were all excellently well insulated, the

earth current was very marked, in some cases almost entirely drowning the sound of the voice, while on No. 3, a miserably insulated line, the earth current was comparatively insignificant, and conversation was carried on with the greatest ease. When this line was so nearly dead grounded, that it was nearly impossible to work with the Morse system over it, the telephone worked to a charm. The writer has sought to explain this as follows, which, be it remarked, is only provisional, for the subject deserves more attention than he has been able to give it.

It would be difficult to choose two points, at any considerable distance apart, which would be at so nearly the same potential that when they were connected by an insulated line, no current would pass. If the line were perfectly insulated the electromotive force of the earth current would be proportional to the difference of potential of the points; hence, if this difference were great the current would be great. On the other hand, if the line were leaking, this would allow of the readier equilibration of the potential at the terminus of the line and the leak, and of the difference between any two leaks, so that the earth current arriving at the distant telephone would principally be that due to the difference of potential of the nearest leak to the distant terminus and that terminus. The telephone current, of course, will lose in strength by being divided into so many branches, but being harmonic in its character, the successive currents reinforce the motion of the plate, hence a difference in the incoming current is not so readily perceived, and by adjusting, nearly as loud sounds can be obtained as if the line were insulated.

This observation agrees with the fact observed by others, that two wires could be buried in the ground and yet a telephone circuit made through them. Prof. A. M. Mayer has experimented on a railroad track, using the two rails as conductors and badly insulated and connected at switches as they were, good results were still reached. The writer has conversed with some ease between different floors of the same building, using the gas and water pipes as conductors. The same facts were observed with Mr. Edison's so-called "Etheric force;" and in fact many observations point to a close analogy between these telephonic currents and the "Etheric force," both being rapidly reversed currents. It should be noted that in the above experiments, Nos. 1 and 2 ran northeast and southwest, while Nos. 3 and 4 ran essentially northwest and southeast. No. 4, though

well insulated, was much better than 1 or 2. Such experiments give us some idea of the infinitesimal character of the currents active in this instrument, which, though escaping at every point almost, still arrive at a distance of twenty-five or fifty miles with sufficient strength to operate the telephone satisfactorily. One of the telephones used in these experiments when the plate was pressed in with the finger and held, gave, on a high resistance Thomson galvanometer, a deflection of only 1°. This points to the use of the telephone as a delicate electroscope, especially valuable where reversed currents are to be observed, as in Mr. Edison's "force," and with it very accurate measurement could be made, placing it in the cross of the "Wheatstone Bridge," or winding it differentially and balancing until no "click" was heard in the instrument at closing and breaking circuit. In fact, this is only one of the many uses to which it can be applied other than as a transmitter of speech or music, and from its wide adaptation, its beautiful simplicity, and the marvelous minuteness of the forces involved, it deserves to be classed, as it undoubtedly will be, among the greatest and most interesting inventions.

STEVENS INSTITUTE OF TECHNOLOGY,
Hoboken, N. J., March 30th, 1878.

ON THE EROSIVE AND ABRADING POWER OF WATER UPON THE SIDES AND THE BOTTOM OF RIVERS AND CANALS.

By CLEMENS HERSCHEL, Civil and Hydraulic Eng., of Boston.

[Continued from Vol. lxxv., page 338.]

Dubuat also pursued the inquiry somewhat further, and observed what became of the sand after it had started. His Sec. 72, Vol. 1, is very interesting on this point. Says he: "When the velocity on the bed of the stream is great enough to cause bodies heavier than water to roll or slide along, these bodies are not moved along with uniform velocity, but they travel, as it were, by relays. Let us take the sand for example. When the bottom of the channel is composed of sand, a little coarse and well visible, and the velocity there is 0·67 or 1·00 ft. per second, its appearance resembles that of what is known as Hun-

garian lace, forming irregular furrows at right angles to the current." Then he goes on to describe the well known wrinkles to be observed in all sandy streams, and how the sand rolls up the flat upstream slope, and rolls over the crest, down the steeper downstream slope of these furrows, to be buried up by the next grains of sand, and so on.[1] "In this way," he says, "as a mean result the same grain of sand requires two years to travel 3 miles. If the velocity increases, it goes faster, if it diminishes, it will go slower." The statement is sometimes met with, that Dubuat said that a velocity of 2 feet per second made sand travel, in the above way, about 10 miles per annum. The only authority the writer has been able to find for this is the remark of Dubuat, that in the river Hayne it took sand 2 years to go from Mons to Condé, about 20 miles apart, and the average of the 4 measurements of the Hayne velocities given in the book is about 2 ft. per second at the surface and centre of the stream, varying from 1·33 to 3·00 ft. per second. But the value of this statement may be somewhat shaken in the minds of some, when introduced, as in the original, by this remark, Sec. 400, Vol. 2: "This river does not erode sand itself, for it flows in a clay bed, ordinarily; but at Mons they are in the habit of sanding the floors, and then they sweep the sand into the streets, where it is left in little heaps; the rain washes these into the river, whence it is carried, little by little, down to Conde, requiring apparently more than 2 years to go this distance, which is about 21 miles." Dubuat must be credited, however, with having recognized that his experiments were but a beginning, and that they should not be rated too high—a piece of warning that the three subsequent generations seem to have neglected to a surprising degree. Says he, Sec. 396, Vol. 2:

"It is only by studying the course of the rivers of a kingdom, or even of all the different parts of the earth, in a thorough manner, that one could flatter himself to have gathered sufficient observations to be able to assign the proper degree of tenacity to every species of earth, and to determine the proper velocity of any stream, so that it shall neither erode its bed, nor form deposits. There is so great a variety in the combinations of the different materials which constitute

[1] For an example of the same thing on a very large scale, and in nature, see the report of Genl. G. K. Warren, U. S. Engrs., on "Fox and Wisconsin Rivers Improvement," Report of Chf. of Engrs., U. S. Army, 1876. Also separately printed; p. 73 of this edition.

the bed of a stream, that there cannot be any general rule for the determination of this velocity. Intelligent travelers would render a great service to science, if they would carefully observe the velocity at the surface of the different rivers of the earth, their mean cross-section, and the nature of the soil in which they flow. But observations of this kind cannot be made and gathered together, except in a great length of time, and it seemed proper to make at least an attempt in this direction, by the use of our experimental canal. It is with these views that we undertook the experiments now about to be described."

Robison's Mechanical Philosophy, about 1800, is often quoted from by English writers; but Dr. Robison, not having had opportunity to experiment, was obliged to confine himself to a discussion of the results found by Dubuat; and so with a host of other writers, who have repeated Dubuat's data for the movement of clay, sand, gravel, size of aniseed, peas and beans, one inch in diameter and the size of a hen's egg, in two little plank troughs, the bottom velocity being measured by the *rolling* along of some gooseberries that happened to be handy at the time, until it has become heresy to doubt any conclusions that may or may not be drawn from them. Dubuat's own words, quoted above, should teach us in which direction the path of duty lies.

The next writer in order of time, who gave the profession original data, was probably Umpfenbach, towards the end of the eighteenth or beginning of the nineteenth century. In default of the original work, the data given by him are here reproduced from an article by Prof. Sternberg, of Carlsruhe, Baden, which appeared in the *Zeitschrift für Bauwesen*, 1875, p. 495. Umpfenbach is there reported as having observed, following the hint given by Dubuat, perhaps, that when the velocity, at the surface and in the centre of "small brooks," was as given in the first column, the diameters of the pebbles, of which their bed was composed, were as in the second column.

Max. Surface velocity in "small brooks." Ft. per sec.	Diam. of pebbles. Inches.
3·1	1·0
5·2	2·0
7·1	7·0
10·0	12·5
15·0	15·5

In the same article is found this statement made by Funk, also one of the earlier German writers on practical hydraulics, who generally wrote concerning the Weser, when he spoke of rivers, that with a maximum surface velocity of 5·6 ft. per second, the bottom was composed of granite shingle 2 ins. in diameter.

Somewhere about this time, 1820 odd, originated the formula given in "Stevenson on Harbors," page 157, quoted from Sir John Leslie; $v = 4\sqrt{a}$, "where a denotes, in feet, the side of a cubical block of stone, or diameter of a boulder, and v equals the velocity of the water in miles per hour, which is capable of moving it along the bottom." But really, if any one will refer to the original, page 392 of Prof. Leslie's "Elements of Natural Philosophy," Edinburgh, 1823, he will hardly thank Mr. Stevenson for having encumbered our harvest with this well intentioned, no doubt, but not very valuable bit of chaff among the grain. It is a formula that is evolved from purely theoretical reasoning on the impact of water, etc., and is finally modified by liberal assumptions. Taken altogether, the final conclusion left in the mind of the student, is that this formula may or may not represent the relation between velocity and size of cube, or sphere. [The formula is evolved for a cube, and it is then stated that it will be "nearly the same" for a sphere.] It will be better, not to consider it all in conjunction with the results of experiment, even when these latter have been somewhat crudely conducted.

The experiments of Dr. G. Hagen, (late "Ober-Landes-Bau-Director,") Chief of the Engineering Department of the Prussian Kingdom and its Provinces, come next, perhaps, in order of time.[1]

The works of this writer do not seem to be so well known to English and American engineers as they ought to be; but they are standard works in Germany. As an engineer of some fifty years' experience, who commenced his career under the severe schooling of the well known astronomer, Bessel, and who has made it his aim to introduce into the study of engineering principles the same careful weighing of scientific testimony that has produced such marked results in the study of astronomy, anything said by Dr. Hagen on matters of engineering, merits the close attention of the reader.

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[1] See "Handbuch der Wasserbaukunst," in three parts, ten volumes in all. First two parts on water-sources, water-works, foundations, rivers and canals, in the third edition (1871–74.) Third part, works upon the sea, first edition, 1864. Berlin, Ernst & Korn.

Says he, Article 21, Part II, 3d edition: "I made the attempt to repeat them [Dubuat's experiments], using various kinds of sand, but I could not discover that there was any definite relation between the velocity and the ease with which the various sizes of sand were set in motion; at certain places where the cross-section was smaller, and hence the velocity was greater than at other places, the sand lay perfectly solid, and had been heaped up, while it had been washed away from the places last named. In large rivers, also, cases may frequently be found which confirm the experience last cited, and which show no erosion by the water, but, on the contrary, an increase of shoaling in those cross-sections wherein the mean velocity is evidently a maximum." And § 7: "In natural channels of rivers, there are many places which are notably deeper than the rest of the river, the ('pools'); one would think that these pools ought to fill up with particular rapidity on account of the decrease of velocity which they occasion, but such is not the case, and their depth remains the same, even though the pool should change its precise locality. On the other hand, there are places which have always been known as shoals and bars; they have repeatedly, and some of them have at every low water been dredged out, and yet every flood will deposit stones and sand anew in them." And in Article 8: "It is of great importance to know *in what manner it is that the water erodes the banks;* without doubt, this requires the expenditure of a certain amount of force, and this can only be generated by the motion of the water. It may be assumed, therefore, as a general proposition, that the action of the river will be greater, the greater its velocity. This is confirmed by experience, but it nevertheless remains questionable whether a *uniform* and rapid current will erode the banks; that is to say, a current in which the particles of water move parallel to the banks with a certain velocity; or whether this is not a matter less of velocity of the whole mass of water, and more of the partial and *inner movements* of the particles among themselves, and of the *whirl-pools* which are known to consume a certain portion of the vis viva of the moving water. All experience tends to confirm this latter assumption; it may be doubted only in so far, that both kinds of movement of the particles among themselves, and of them altogether in line of the current, increase and decrease, the one with the other, so that it cannot be decided which of the two was the cause of the erosion that has taken place." And the subject is further discussed

philosophically and at length in Article 21. These are strange sounding words to the orthodox believer in the motion of water in straight lines or "filaments," to the devotee of "fluid veins," and of horizontal "layers" of water under all circumstances; but these notions, also, it is time were rudely shaken, especially in English literature upon the subject. It will no doubt be universally recognized before long, that it is only in the case of small and extremely regular bodies of flowing water, if at all, that these notions can be made to apply. But in natural streams such conditions rarely exist, and the artificial canals, and even pipes, that have the regularity of experimental channels, are few indeed.

These inner irregularities of motion, just spoken of, were, however, studied so early as 1791, by Venturi,[1] at Modena, whose experiments were published in Paris, in 1797, under the title "Récherches experimentales sur le principe de la communication latérale du mouvement dans les fluids."

On page 165 of the "Tracts on Hydraulics," this lateral communication of movement in fluids will be found discussed in its application to rivers, and it is more than hinted at that this is the prime cause of the erosion of the bed and the shores of rivers.

In 1848 was published a book by J. Dupuit, an eminent engineer of the "Corps des Ponts et Chaussées," and an original thinker and writer on various engineering subjects, entitled "Études Théoriques et Pratiques sur le Mouvement des Eaux Courantes," which has since appeared in a second edition. Says M. Dupuit, in the preface, page xi: "We have attempted to prove by numerous examples that these sort of questions are eminently complex; that their solution depends on a great number of local circumstances of various elements, which can neither be expressed nor combined mathematically. Mathematics is to the engineer what grammar is to the writer; it may direct ideas and inventions, but it cannot produce them. The phenomenon of the transport and the deposit of alluvial matter is explained to-day either incompletely or erroneously. We present a new theory upon this subject. We show that there are two distinct forces at work in every stream flowing upon a bed that is subject to erosion; the power of dragging along the bottom materials, which

[1] A translation of Venturi's works, in Nicholson's "Journal of Natural Philosophy," vol. iii, London, 1802. Also in "Tracts on Hydraulics," by Thomas Tredgold, 2d edition, London, 1836.

depends on the absolute velocity of the stream, and the power of suspension of the stream, which depends upon the relative velocity of the various filaments among themselves." To the elucidation of this matter, M. Dupuit has devoted the last twenty-two pages of his work, which are to be commended to the student of this branch of practical hydraulics. Says he, page 230, first edition: "If we are to be guided by a few experiments of Dubuat, according to which it would result that for a velocity of 0·30 m. (1 ft.), sand will move at the rate of 2 kilom. (1·25 miles) per annum, and for a velocity of 0·60 m. (2 ft.), it would travel only 13 (8·25 miles), we should say that this power of dragging along, which could, in course of time and by constant action, produce very appreciable effects at any one definite point of the bed, cannot produce anything but very feeble effects upon the whole length of the channel. For we are speaking now of a layer of sand exceedingly thin, and moving with a velocity which is almost inappreciable. But however that may be, there is another force residing in the water which is much more powerful against movable materials, and which has not been sufficiently considered, it seems to us. This force, which we have called the power of suspension, reveals itself in a multitude of phenomena, which leave no doubt of its existence nor of its energy.

"'Gravel is transported not only upon the bed of a stream,' says M. Minard ("Navigation des Rivieres," p. 17), 'but also is elevated and is thrown upon the shores. The dykes of the Garonne are sometimes broken during floods, and after the subsidence of the water, volumes of 6000 to 8000 cubic metres of gravel are found on the recently cultivated territories. I have seen such masses of sand, which, after having passed through breaches in the dykes on the Loire, were two or three metres higher than low water of the river.' And we could, if there were need of it, confirm what M. Minard says by similar facts observed upon the Loire; but it seems to us that they are too well known to be denied.

"Since deposits are formed upon the shores, two or three metres above low water mark, and consisting of enormous masses of gravel and of sand, it is very evident that this gravel, this sand, has been in suspension in the water; for gravel and sand dragged along the bed of the stream could not pass the breaks in the dykes and place itself in masses upon land, which is several metres higher than this bed. No other explanation is possible for this phenomenon than the

one given of the suspension of the solid matter in the water of the stream. Besides, it is easy enough to convince one's self of this property of liquids and of fluids, by excessively simple experiments; we said fluids, just now, because gases have the same property: witness the elevation by the wind of clouds of dust, and in gravelly countries carrying even gravel to a great height and producing effects entirely analogous to those that have been cited." Then after explaining how it is that a difference in the velocity of contiguous filaments or small portions of a large stream of water can move a body floating upon the surface, laterally, M. Dubuit says: "The difference in the velocity of the filaments in making unequal currents pass to the right and to the left of the floating body, engenders a power which will push it towards the filaments that flow with the greatest rapidity. This is confirmed, moreover, by daily experience: a floating body tending to detach itself from the shores and to reach the thread of the current. If we should now imagine a solid body plunged into a stream, we shall see that the relative velocity of the filaments, in a vertical, will engender a similar kind of pressure, tending to push the body towards the most rapid filaments, that is to say, acting from below upwards." And after further discussion, the results of the investigation are thus summed up: "Flowing water can hold bodies in suspension which are much more dense than it. The power of suspension depends upon the relative velocity of the filaments, and is greater, the greater this relative velocity is. Generally speaking, it varies with the quantity:

$$\frac{dv}{dz} = \left[\frac{\text{diff. velocity}}{\text{diff. depth}}\right],$$ so that the lower planes of the stream can carry more voluminous solids, or more of them, than those higher up."

The power of suspension of any layer is limited, that is to say, a square metre of that layer can contain only a certain number of solids of a certain size. Thus, each layer has its own different degree of saturation. It is then explained why a shallow brook will run clear at a velocity, which in a deep river might *lift up*, not roll along, sand and gravel; how it happens that rivers deposit finer and finer materials from their sources downwards; why pools are not filled up, and shallows deepened, and more of the same sort.

Mr. Thomas Login, Mem. Inst. C. E., in the *Artisan*, 1869–32, also speaks of the whirling or rotary motion of water as effecting

scour. Says he, in speaking of the way in which bridges and other works that guide water should be built, in order that they may not cause the water to undermine their foundations, the engineer "must take care that the water flows off smoothly, that is, that there be as few eddies as possible on leaving the works; but as this rolling or whirling motion cannot on all occasions be avoided, a slight increase of sectional area is necessary. Again, in nature, we never find that water flows in straight lines, but has either a whirling, or what appears to be a rotary motion, that is, any particle of water moving down a stream would follow the course of any point on the perimeter of a carriage wheel rather than that of the axes." On the other hand, in speaking of the Solani aqueduct, "a perfectly smooth, uniform channel, with perpendicular sides, and having no obstructions, either from bends or from irregularities of the bed, with a volume of water, nearly equaling 3000 cubic feet per second;" 85 feet wide, and over 900 feet long, 8·2 feet deep, and a bottom velocity of 2·60 to 3·80, averaging 3·47 feet per second, Mr. Login "found that a deposit of sand had actually taken place where the bottom velocity was three times what would be sufficient for transporting sand."

Before leaving this branch of the inquiry, the writer may offer a few reflections of his own. The traveler on the lower Mississippi floats upon a mighty river, from 2200 to 5000 feet wide, averaging about 3300 feet; from 70 to 180 feet deep, averaging about 115 feet; its velocity at the surface and in the thread of the current is about five miles per hour (about 7·5 feet per second); being a series of bends, some of them exceedingly sharp and sudden, there are produced the most violent irregularities of current; in the vicinity of a sharp curve, especially, there may be seen immense whirlpools, whose final actions and effects it would be impossible to follow to the end; but we know from observation that there are in such localities all sorts of under currents, exceeding the surface velocity, currents along shore, that run up stream at the rate of 1 or 2 miles per hour, and similar anomalies. The wonder is not that such a river should erode its banks, but how it is that clay, fine sand and mud can at all contain it. On the other hand, every engineer who has been along the seacoast will have noticed places where the tide will run on the ebb at the rate of 2 and 3 miles per hour, 3 and 4·5 feet per second, *in beds of pure sand*, and yet such channels will not become deeper, but will often fill up, on the contrary, and narrow up without any apparent cause, gradually

and slowly; they *diminish* their cross-section down to a certain limit, that is entirely unexplainable by theories of the action of the absolute velocity of the current alone, when speaking after the manner of Dubuat, as usually quoted; and reasoning from the result of experiments of this kind. But if attention be directed to the regularity of flow in such tidal streams, it will be noticed that they are generally quite shallow, running dry at low water, not infrequently, and that their flow is very regular and smooth, so that we have here a case of a very thin layer of sand moving from 5 to 10 miles in a year, according to Dubuat, that is, at the rate of about 0·0008 to 0·0017 feet per second. Whence it is explainable why such streams do not attack the bed of sand in which they flow to any appreciable extent.[1]

In an article in the "Annales des Ponts et Chaussées," 1868–1–34, on river navigation, by M. Fargue, Ingenieur des Ponts et Chaussées, and which, by the way, is unusually replete with facts and figures, the author comes to the conclusion that the shoals and pools and the scouring power of the section of river, fourteen miles long, under discussion, are regular functions of the situation and curvature of the bends of the river. His investigation seems to prove that a river will have the most regular and uniform depth of water when confined by artificial banks, whose curves consist of, and are joined to, the straight reaches by curves of the higher degree; or, if made of circular arcs, when they consist of compound curves, and whose tangents are those of what are called in mathematics osculations of the second and higher degrees instead of being simple tangents, as when

[1] The cases here spoken of are not those of sand-bar formations, or similar cases, in which the action of the waves in throwing up sand forms an element of the problem. The impression is very clear in the writer's mind, that he has read somewhere, that in Holland, in the case of small channels leading across areas of mud-flats, the depth of these channels is increased, and they are maintained in the same situation by anchoring a row of casks along their centre line. If this is true, and the writer regrets not to be able to refer to the authority, when he may be mistaken about it altogether, the explanation would be that the ebb and flood currents cause whirlpools around the casks which deepen the channel under them, and the row of anchored casks thus makes and maintains a continuous fore-and-aft channel. Since writing this much, the writer has found a form of channel producing construction, composed of a row of small piles connected by a chain, described in the "Annales du Genie Civil," 1876–96. It is there translated from the Transactions of the Holland Society of Civil Engineers, and is highly commended. After successful operation in small channels, it was about to be tried on a large scale.

a circle is drawn tangent to a straight line. He proposes to build a section of the river works, then about to be constructed upon this principle, and hopes to attain a more uniform depth of water by this means than he could otherwise expect. M. Fargue, similar to other writers which have been quoted, calls attention to the fact that "the ordinary hypothesis of the flow of water in parallel filaments, is absolutely inapplicable to the flow of rivers." And then goes on to show how the different portions of a river interchange places and penetrate each other.

ILLUMINATION BY ELECTRICITY.

By J. JAMIN, de l'Académie des Sciences.

Condensed from the *Revue des Deux Mondes*, of March 15th, 1878, by Dr. William H. Greene.

The Gramme machine, as the electric source, and the Jablochkof candle have made the application of electricity to purposes of illumination, a fact beyond doubt.

The intensity of the moon's light is inferior to that of a candle, and incomparably more feeble than that of the sun.

The comparison of the electric arc to the sun, which is our highest conception of brilliancy, may be made in two ways; by the relative times required to produce equal photographic images, or by the direct measure of the illuminating powers. Fizeau and Foucault found by the first process that the power of the sun is only two and a half times superior to that of the arc; the second method has proved that the carbon points with a powerful machine are equal to the sun in lustre. It is even probable that this limit may be passed, and it is not strange, if it be remembered that our sun does not occupy the first position in the universe. It is a star already old, the cooling of which is considerably advanced and whose yellowish light begins to approach that of terrestrial flames.

In quantity and quality, the electric light greatly exceeds all flames, and in brilliancy it approaches or even surpasses the sun. It

is precisely this immense profusion of illuminating power that is urged against the electric light. It is said to be exaggerated, to exceed our requirements, that it ought to be divided, but it is indivisible.

It is true that the electric light is dangerous, like that of the sun; we may be illuminated by it, we should not look at it. But is it by any means certain that it cannot be divided or so reduced in lustre as to be rendered tolerable?

Nothing is easier than to reduce its lustre to any degree that may be desired; it is only necessary to cover the arc with a large opalescent globe. The latter hides it, receives all of the rays and dispenses them precisely as if the globe itself were luminous. It replaces the original source, at the same time increasing the dimensions, and if it be ten thousand times larger, it reduces the lustre to the ten thousandth part. It is true, this process absorbs and wastes a notable portion of the light emitted, but where the electric light can be adopted, this is of but little importance. The division of the arc can easily be accomplished by the use of the alternative currents long since devised by Le Roux, for when the alternations succeed each other at intervals of one-twenty-fifth of a second, the extinction ceases to be perceptible, and the effect is that of a continuous light. The Jablochkof candle, when the thickness and distance of the two carbons are diminished, permits a still further division, so that each candle may equal but fifty Carcel lamps, and a number of these candles may be placed in the same circuit.

The division may be carried still further, as shown by a new and remarkable experiment of M. Jablochkof's. He prepares an immense condenser composed of two tinfoil surfaces, separated by oiled silk, and folded as the condenser of a Ruhmkorff coil. The surfaces are connected with the two rheophores of an alternating current machine, so that a large space is presented on which the electricity may accumulate and condense until the direction of the current changing, each disappears to be replaced by the opposite electricity, which, in its turn, undergoes the same condensation. It is evident that these conditions should greatly modify the electric circulation in the wires, and experiment confirms the assertion. When the current is broken, brilliant sparks are produced, flashing like fire, and enveloped in a very luminous yellow flame, at the same time accompanied by

a sonorous humming sound, of the same pitch as the noise of the machine, which proves that the periodic intervals of the production of the sparks are the same as those of the formation of the currents. This experiment leads to one practical result; it is that by introducing a condenser into the circuit, the number of candles that the latter is capable of sustaining is doubled, but the light of each candle is, of course, reduced one half. All is reduced to a greater division of the illumination. It is not desirable to go beyond this point, for the Jablochkof candle, with the condenser, gives a light equal to twenty-five Carcel lamps, and, in order that electricity may be adopted as a source of light, its power must be equal to that of at least twenty Carcel lamps.

M. Jablochkof made another interesting experiment; he passed the alternating current through the interior wire of a Ruhmkorff coil, producing in the exterior wire induced currents also alternating, but of greater intensity, which are capable of diffusing upon the edge of a thin piece of kaolin, illuminating it, and maintaining the incandescence as long as may be desired. It is a beautiful physical experiment, but its practical application is doubtful.

The light of a gas flame is orange yellow when compared to that of the electric light. That a light may be applicable for purposes of illumination, it is necessary that it shall contain the seven primitive colors of the spectrum in certain proportions. All luminous bodies do not contain these colors in the same proportions. The electric arc produced between silver and carbon, contains only two green bands, and if the silver be replaced by other metals, the spectrum obtained is always formed of brilliant lines separated by wide, dark spaces. These lights are very incomplete, and would not, in any case, be used for illumination.

The spectrum of gas and oil flames are continuous; the red, orange and yellow are very abundant; there is but little green, almost no blue, and little or no violet. These flames are rich in colors but slightly refrangible, which gives them their orange tint, poor in highly refrangible rays and destitute of indigo and violet. That of which they possess too much, the red, may be removed, but it is impossible to add to them the indigo and violet which they lack, and this is the cause of their inferiority. The electric light is more complex; it proceeds at the same time from the

carbons and from the arc, and differs according to the one or the other of the sources. That from the carbons is white; it is absolutely the same as that of the sun, and contains all of the simple rays in the same proportions. It is complete and perfect and replaces daylight without any modification. It is not the same with the light from the arc itself; it is violet blue, and its spectrum tends altogether towards the most refrangible colors; it is the opposite of gas- or lamp-light; it contains little red, much blue, and a large excess of violet. It is this light of the arc which gives to electric illumination the bluish tint which has been objected to with reason. But it is a fault of excess which can be remedied, for while the missing rays cannot be added to gaslight, the superfluous rays can be removed from the electric light. The eye receives the vibrations of the ether which constitute light, just as the ear receives sounds transmitted by the air, and ceases to be conscious when the vibrations become so rapid or too slow, just as the ear ceases to hear notes too acute or too grave. But such extreme vibrations exist; there are rays below the red and beyond the violet, both of which are imperceptible to our eyes. The first are the heat rays, so abundant in the spectre of flames, the second exist in large proportion in the light of the arc, and are those which it is important to recognize and remove. Their existence may be proved in two ways, first by receiving the spectrum upon a photographically sensitive surface. The image formed in the red is very feeble, while those formed as the violet is approached become better and better; but the action does not stop at the violet. The photographic intensity is extended and increases beyond the violet, which proves the existence of ultra-violet rays of rapid vibration which our eyes cannot recognize, but which are eminently fitted for photographic action. The second method is different. If a solution of quinine sulphate be spread with a small brush upon the spectrum from the red to the violet, no effect is perceived in the red, but after the blue a whitish tint marks the path of the brush, and this is increased and becomes most brilliant in the rays which are beyond the violet. The quinine sulphate has, therefore, the property of changing the blue, violet and ultra-violet rays into white light, and, at the same time, it renders visible and useful, radiations which the eye could not perceive, and adds them to the available light.

Uranium glass and many other substances act in the same manner and present the means of suppressing the rays which are objectionable in the electric light. This suppression is necessary in other respects. These rays are said to attack the humors of the eye, and to be the origin of grave diseases.

But the electric light has its faults, one especially which will exclude it from many places. It produces a grave continuous note like the buzzing of a swarm of flies or an æolian harp. It is not a disagreeable note, but it becomes monotonous. It is produced by the succession of alternating currents lighting and extinguishing the arc at each change of direction, with a little noise each time. As this noise is produced at equal intervals, it becomes a tone, the same as that produced by the machine, and when the candles are placed in globes, the latter become resonators, and increase the sound. The Gramme machine is the only one which furnishes a silent light, because its current is continuous in the same direction.[1] The electric light, however, does not vitiate the atmosphere, and produces very little heat.

In ordinary flames, the production of light is a secondary phenomenon which accompanies the chemical combination of the combustible with the oxygen of the air. This combination is doubly objectionable, removing the oxygen from the air, and replacing it by vapor of water and carbonic acid gas. The latter, although not as dangerous as has been believed, has not a good reputation, and the best that can be said in its favor is that it does not kill. The electric light has the decided advantage of not altering the respirable medium. Chemical combination has still another inconvenience: with the light it develops such an amount of heat as sometimes to render work-rooms almost uninhabitable.

On the contrary, the electric arc does not heat. This appears astonishing at first, for all bodies fuse or volatilize when introduced into the arc; but if a very sensitive thermometer be placed in the spectrum of the electric light, it is found that there is no indication of heat in the violet rays; that in the green the thermometer begins to be heated, and that the temperature continues to rise as the red is approached, and attains a maximum in the obscure rays beyond the

[1] In the experiments made by the Committee of the Franklin Institute, it was found that all of the so called continuous current machines produced some sound in the arc.—J. B. K.

red. Now these heat-producing rays are by far the more abundant in gas and lamp flames, while the arc, which is the best test of luminous sources, emits the greatest amount of light with the least proportion of heat.

The exact cost of the electric light is yet a matter of question, but the Lontin Company furnish all of the apparatus, wires, lamps, etc., of which it retains the ownership, and demands fifty centimes an hour for a quantity of electricity, equal to 100 gas jets, on the condition of a guarantee of the use of a certain amount of light for a certain number of years. One of the proprietors of the magasins du Louvre has authorized the statement that the apparatus of the Denayrouse-Jablochkof Company, in their use, gives more light than gas with 30 per cent. less cost.

The fault has often been committed of attempting street illumination on the lighthouse system by a beam of light concentrated by reflectors, and thrown along the length of the street. Such experiments have only succeeded in blinding the by-passers and projecting behind them long shadows as black as open precipices. There are cases when such concentration is the only end that is desired. In workshops, it is only necessary that the workman shall have a clear view of the work before him. It is the same in dining-rooms, billiard-halls, reading-rooms, etc., and no one pays attention to the obscurity behind him.

It is different in depots, theatres, lecture-rooms and display store-rooms; in these cases a general illumination is required, coming from all directions, and lighting every side of an object.

When several electric lights are placed in a hall illuminated by gas, the eye immediately experiences a sort of relief, both by the redoubled brilliancy and by the perception of colors which were not before suspected; and, on the contrary, if the electric lights be suddenly extinguished, the spectators are thrown into the comparative night of the old illumination.

The conditions of good electrical lighting must be determined by a study of the general illumination of objects during the day. When the sky is clouded, the sunlight pierces the clouds as through a ground glass, and the whole sky is like an immense illuminated ceiling, radiating light from every point and in all directions. The objects illuminated diffuse in their turn the light which they receive,

so that there is an inter-crossing of rays, producing the effect of a mean amount of light everywhere; this is *general illumination.*

Such is the model that must be followed. For this purpose the ceilings, walls and floors must be well illuminated, that the diffused light may be radiated into the empty spaces; and, that the quantity may be the same everywhere, it will be necessary to multiply the sources of light. That the direct rays may not painfully affect the retina, it will also be necessary to diminish their brilliancy by the interposition of ground glass and some florescent substance, such as quinine sulphate, in order to transform the violet and ultra-violet rays into white light. Lastly, and especially, it will be necessary to cover all openings by which the light may escape.

The exterior light enters by the windows during the day, and it is by them that the nocturnal illumination escapes. M. Jablochkof introduced electric lighting into the laboratory of the Sorbonne, and the feeble effect it produced was astonishing. This laboratory is covered with a glass roof, by which it is well lighted during the day, and by which it allowed the loss of at least one-half of the light produced by the electric candles. This wasted light illuminated the high walls of the surrounding buildings, and gave a brilliant but useless illumination in the court. A similar occurrence took place last summer on the occasion of an experiment attempted in the Palais de l'Industrie. All of the light had been concentrated in six lamps, far from each other; this was the first fault which would have been avoided by distributing a large number of less powerful lamps throughout the immense building. Lastly, all of this light, instead of being directed towards the spectators by a well-combined system of diffusion, escaped through the vast glass roof, to be uselessly lost in the heavens. The experiment would have succeeded had the roof been covered with a thick white covering, destined to reflect back the light so prodigally wasted.

The same thing happens with gas, and will occur with electricity in the illumination of public places. All of the lamps waste half of their light in radiation towards the sky. A simple reflector would return it to the ground and double the illumination.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. lxxv, page 201.]

Other methods for the industrial conversion of sodium nitrate into potassium nitrate are probably no longer in use. In an early process the potash salts from the manufacture of beet-root sugar were utilized. The aqueous solution contains principally potassium sulphate, chloride, and carbonate, and sodium carbonate. On concentration to specific gravity 1·38 (40°B.) the sulphate of potash separates out whilst the liquid is hot, and the greater part of the chloride on cooling. The mother-liquor separated from these salts was mixed with Chili saltpetre and concentrated further, when carbonate of soda, mixed with more or less chloride of sodium, was deposited and fished out. The clear mother-liquid, on cooling, deposited potash saltpetre in crystals.

Another method, proposed by Landmann,[ii] was in use for some time in England, and was also employed by Nöllner[iii] at Billwerder, near Hamburg, at the time of the Crimean war. It depends on the decomposition of caustic potash and Chili saltpetre, yielding caustic soda and potash saltpetre. The latter is crystallized out, and the former evaporated down, and sold as lump caustic soda. According to an account by G. A. Scherf,[iv] the following rather circumstantial process is used in America for the simultaneous production of potash saltpetre and baryta-white, by reason of the heavy duty on salt and the high price of hydrochloric acid. Chili saltpetre is converted by chloride of barium into nitrate of barium and chloride of sodium. Stassfurt chloride of potassium is converted into sulphate of potassium and hydrochloric acid by heating with sulphuric acid, and the sul-

[1] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

[ii] Landmann, *Dingler*, cxvii, 78.

[iii] Nöllner, *Polyt. Notizbl.*, 1867, 370.

[iv] Scherf, *Wagner*, 1866, 227.

phate of potassium thus obtained is finally converted by treatment with the barium nitrate into potash saltpetre and baryta-white.

We have still to mention Delafield's[i] proposal for the simultaneous manufacture of white-lead and potash saltpetre. He precipitates a boiling solution of nitrate of lead with carbonate of potash, when a carbonate of lead, agreeing in composition and properties with white-lead, is thrown down, whilst potash saltpetre remains in solution, and may be obtained by concentration.

In the technological analysis of nitrate of potash, the chlorine is generally determined volumetrically by means of silver nitrate, with chromate of potash as indicator; the sulphuric acid gravimetrically as barium sulphate; the potassium as the double platino-chloride, and the water and insoluble constituents by direct weighing. From these data the composition is calculated. A special examination must be made for sodium nitrate. This is most conveniently carried out according to the proposal of Nöllner,[ii] by moistening a portion of the sample—not too small—with a little water, evaporating the solution to dryness, moistening the saline residue again, and re-evaporating the lixivium. The whole amount of the very soluble soda saltpetre may be in this manner collected in a very small quantity of liquid, so that it may be recognized by its rhombohedral crystalline form, and especially by its characteristic optical behavior under the microscope with the polarizing apparatus. If it is desired to determine the nitric acid, this is, for technological purposes, best effected by mixing the sample intimately with sugar, graphite,[iii] or oxalic acid, and igniting after the addition of from 4 to 6 parts of common salt. The fused mass is lixiviated with water, and the carbonate formed is determined volumetrically with normal sulphuric acid, from which the nitrate is easily calculated. A number of other methods have been proposed, which in experienced hands give accurate results, but which are either too circumstantial for practical use, or without due care may easily lead to serious errors.

The application of potash saltpetre in the manufacture of gunpowder, and of the nitrates in fireworks, is known. Latterly, Chili saltpetre has been used according to the suggestion of Knowles,

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[i] Delafield, *Chem. News*, 1866, xiv, 178.

[ii] Nöllner, *Polyt. Notizbl.*, 1867, 306; *Dingler*, clxxxvi, 333; *Wagner*, 1867, 241.

[iii] Abel and Bloxam, *Chem. Soc. Quarterly Journal*, x, 107.

made as early as 1858,[i] by Hargreaves,[ii] Heaton,[iii] and Bessemer,[iv] for the decarbonization of cast-iron in the manufacture of steel, and, according to the opinion of Schinz,[v] and Gruner,[vi] has given satisfactory results. R. Wagner[vii] calls attention to the applicability of nitrate of soda in the metallurgy of copper and nickel, for the removal of sulphur from the concentrated ores, and of arsenic from the nickel speiss.

Nitric Acid.—In the industrial preparation of nitric acid, Chili saltpetre and common sulphuric acid are exclusively used, and none of the numerous proposals for obtaining it in any other manner have been carried out on the large scale. The respective proportions of sulphuric acid and of soda saltpetre are not alike in all manufactories, some using but little more sulphuric acid than the equivalent of the nitre, whilst others to 1 equivalent of nitre take as much as $1\frac{3}{4}$ equivalents of sulphuric acid. In the former case the residual sulphate is very sparingly mobile, and must be taken out of the retorts in lumps when cold. In the latter case the bisulphate formed reduces the melting point of the residue so far that it can be easily run off in a liquid state.

The degree of concentration of the sulphuric acid is regulated according to the strength of the nitric acid to be prepared. Ordinarily, sulphuric acid is used at specific gravity 1·718 (60° B.), as obtained by concentration in lead pans. Experience has proved that with this strength the mixture froths least, so that the retorts may be charged tolerably full. The average strength of the nitric acid thus obtained varies with the quantity of sulphuric acid used and the heat applied, but ranges in general between specific gravity 1·38 to 1·41 (40° to 42° B.). For the preparation of weaker kinds this acid is diluted with water, which is placed previously in the condensing apparatus. For stronger nitric acid a more concentrated sulphuric acid must be taken, and for nitric acid of specific gravity 1·50 to

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[i] Knowles, *Repert. Patent Inv.*, 1858, 239; *Dingler*, cxlix, 317; *Wagner*, 1858, 14.

[ii] Hargreaves, *Mech. Mag*, 1868, 11, 30; *Dingler*, clxxxvii, 480; *Wagner*, 1868, 84.

[iii] Heaton, *Dingler*, clxxxvi, 489; *Wagner*, 1868, 87.

[iv] Bessemer, *Prakt. Mech. Journ.*, 1868, 143; *Dingler*, cxc, 32; *Wagner*, 1868, 88.

[v] Schinz, *Dingler*, cxcv, 126; *Wagner*, 1870, 70.

[vi] Gruner, *Comptes Rendus*, lxx, 521; *Wagner*, 1870, 70.

[vii] R. Wagner, *Wagner's Jahresber.*, 1870, 116, 151.

1·53 (48° to 50° B.), which almost corresponds to the pure monohydrate, dried Chili nitre, and oil of vitriol at specific gravity 1·85 (66° B.), must be used.

The apparatus employed consists in general of horizontal cast-iron cylinders, set so that they may be enveloped as equally as possible in the hot furnace-gases. In some works an attempt is made to protect the upper half of the cylinder from corrosion by the acid, by means of a lining of bricks or a coating of fire-clay. This arrangement is, however, useless if the iron is kept so hot that no nitric acid can be condensed upon it. The expedient may even have an injurious effect, since the porous mass of clay is less strongly heated than the metal, and easily retains a portion of nitric acid, which, when the cylinder cools, may attack the iron. The two ends of the cylinder are not exposed to the fire, and are therefore best closed with plates of sandstone luted with a mixture of iron-filings, sal-ammoniac, sulphur, and vinegar. This luting sets rapidly, and resists the action of the fire and of the acid very well. The front end slab has in its upper half an aperture which serves for the introduction of the nitre, and can be closed with a stone stopper luted with clay. In this stopper is a smaller orifice, through which, when everything else is arranged, the sulphuric acid is run in by means of a lead pipe. At the lower part of the front of the cylinder there is a concavity with a hole 8 centims. in diameter, through which the liquid sulphate of soda is removed at the end of the operation. During the process this hole is closed with a cast-iron stopper luted with clay. The back stone slab is perforated to receive a fire-clay pipe, which connects the interior of the cylinder with a series of stoneware jars which serve as condensers. The uncondensed gases are passed into a coke-tower, where they encounter a descending shower of water, which condenses the last traces of nitric acid, and with the joint action of air converts into nitric acid any hyponitric acid present. The stoneware vessels (*bombonnes*) are generally of the same form as those used for hydrochloric acid. Each has two wide apertures for the connecting pipes, and a smaller one for drawing off the acid.

Devers and Plisson[1] have modified the form of the condensing apparatus, so as two jars are placed one above the other in such a manner that the upper is fitted like a funnel into the middle aperture

[1] Schwarzenberg, "Nitric Acid," in Bolley's "Technologie," ii, 1, 2, 304. Brunswick: 1865.

of the lower. The acid as it condenses flows into the lower jar, and from there, through a syphon luted in, to a large receiver. At the end of the condensing plant there are still several jars placed upon each other, and filled with fragments of pumice, in which the hyponitric acid is condensed by a current of water. If about equal equivalents of sulphuric acid and nitre are used, the residual sulphate of soda, as has been already mentioned, is not sufficiently mobile to flow out. The front end of the cylinder is then closed with a cast-iron plate, protected within by a lining of clay. The plate is luted with a mixture of clay and horse-dung, as the iron-lute mentioned above sets too hard. Before charging the cylinder, some prismatic bars of cast-iron with sharp edges are laid at the bottom. On these the cake of sodium sulphate breaks as it cools, and can thus be easily taken out in pieces.

Instead of the cylinders many manufacturers use cast-iron troughs, whose sides are lined with sandstone plates, or with blocks of stone, and which are closed above with a sandstone slab or with a double arch. This arrangement is less advantageous, the outlay in fuel is greater, and the apparatus itself is more readily corroded by the acid.

A preferable construction is a large cast-iron boiler, with a wide aperture above for the introduction of nitre and sulphuric acid, and closed during firing with a cast-iron lid. The boiler is set so as to be exposed to the flames all around and even above the lid. The nitric acid is led to the condensers by a neck cast on to the boiler, and lined with a stoneware pipe as a protection against the action of the acid. The soda sulphate is run out through a pipe cast at the bottom of the boiler. The liquid sulphate is best received in iron boxes standing on small iron trucks, and conveyed away immediately. When cold it is broken in pieces and converted into neutral sulphate (salt cake) for the alkali manufacture by ignition with common salt.

The nitric acid as produced is always tinged more or less with yellow, owing to the presence of hyponitric acid, and contains an amount of hydrochloric acid corresponding to the proportion of chlorine in the nitre employed. It is, further, often contaminated with traces of sulphuric acid, sulphate of soda, ferric oxide, and iodine. To prepare chemically pure nitric acid, the tetrahydrated acid at specific gravity 1·42 (43° B.) is distilled in glass retorts, and the liquid which first passes over is kept separate as long as it pro-

duces a turbidity with a solution of silver nitrate. The receiver is then changed, and the acid is distilled over down to a small residue.

For many technical purposes it is requisite to have nitric acid free from chlorine, whilst the other impurities, when present in small quantity, have no prejudicial effect. Some establishments, for this purpose, wash the Chili nitre with pure water—or, better still, with a saturated solution of nitre free from chlorine—until all the common salt is removed. Others prefer to remove the chlorine after the acid is prepared, which is easily effected by heating the acid in stoneware pans in a water-bath, and simultaneously forcing a current of air through it by means of an air-pump. The escaping hyponitric acid containing chlorine is conducted into a coke-tower. In this manner the nitric acid is obtained as clear as water, and free from chlorine and hyponitric acid.

[To be continued.]

GASLIGHT ENGINEERING.[1]

Comparative Illuminating Effects of Coal Gas, Spermaceti, and Colza Oil. English (American) and French Standards of Measurement of Light.

By Robt. Briggs, C. E., of Philadelphia.

The measurement of the illuminating power of coal gas is estab lished by law in both England and France; each nation adopting its own unit of value, and conditions of burning for the unit material, and for the coal gas measured by it. The English unit is a "standard" spermaceti candle, which must have the size and dimensions known commercially; in 1860, and before, as a "6's" candle, and is taken to burn at the rate of 120 grains per hour. The "standard" candle itself has now a more certain character than it had twenty or thirty years since. Custom, and necessity for a uniform basis of test, have now fixed each detail of size, material, method of making the standard candles much more definitely than descriptions or drawings can express them, until the "standard candles" of any good

[1] From the *Gaslight Journal* of April 2d, 1878.

English maker, under exactly the same conditions of burning, are reliable to give equal light, within the errors of observation by the eye, or within 10 per cent. of probable actual error.

This standard candle, when used for establishing the value of illuminating power of coal gas of different qualities, is compared with a "standard burner." The latter, as usually taken in the country, is a "Sugg-Argand," the dimensions of which are given by English law; but the absence of precise requirements as to form, has permitted modifications which have increased the light-giving effect, one-sixth or one-seventh above what would come from a burner of the form of 1860, without departing from the specified dimensions in the least. The legal requirement demands further that the burner shall consume at the rate of five cubic feet of gas per hour, under a pressure, at the point of ignition, of 0·5 0·6 inch of water column, with a temperature of from 65° to 70° for both air and gas.

The French lawful unit for comparison and measurement of the light from coal gas is a Carcel lamp, of designated construction, which shall burn at the rate of 0·0042 kilo. (0·09250 pound) of colza oil per hour. Every precaution has been taken by the lawmakers to state all the conditions as to construction of lamp and nature of oil, etc., so as to insure uniformity of value for the standard unit; but the result is very little more positive than that from English law, based merely on a trade usage. Perhaps the light from the standard French lamp is slightly more constant in value than that from the English candle. The advantage is solely that of a doubt in its favor.

The French standard burner is a "Bengel" argand, of designated construction, and it is stipulated that it shall be compared with the standard lamp, when burning at the rate of 105 litres (or 3.7083 cubic feet) of gas per hour, under the pressure of from two to three millimetres (0·78 to 1·18 inches) of water column.

The comparison of the English standard candle with the French standard lamp gives 9·6 candle power for the lamp. The candle burning 120 grains per hour, or 0·01714 pound of spermaceti, demands for 9·6 candles, 0·13714 pounds, while the lamp burning its 0·09259 pound of oil in the same time; and it results that the light-giving power of spermaceti to colza oil, the light-giving effects in both instances being the most favorable, is as 1·000 to 1·492. The comparison of the French standard gas-burner with the English one,

in candle units, is an easy one. If 9·6 candles are to be the equivalent to 3·7083 cubic feet in light-giving power, how many candles will be equivalent to five cubic feet? Solution of this sum in the rule of three gives 12·944, or, for practical purposes, 13 candles.

It may be claimed with fairness that average coal gas, having the specific gravity of 0·426, and being generally like the gas which formed the subject of discussion in the paper which appeared in the April number of the JOURNAL OF THE FRANKLIN INSTITUTE (by the writer of this article), may be taken to have an illuminating power of 15 candles; and accepting this value, the comparison of the light-giving effects of coal gas, of spermaceti candles, and of colza oil in Carcel lamps, may be exhibited as follows:

TABLE.

Equivalent to one standard gas-burner.	Weight each.		Total weight.	Weight of material consumed to give equal light.
	wts. =	lbs.	lbs.	lbs.
= 5 cu. ft. gas,	0·426 S. G. =	0·0819 =	0.1595	1·000
=15 candles,	120 grs. =	0.01714 =	0·2671	1·634
=15 / 9·6 =—Carcel lamp 42	9·6 gms. =	0·09259 =	0·1447	0·908

ADDENDA TO PAPER "COAL GAS ENGINEERING."[1]

The table of figures of reduction of volumes to weights may be found to show the percentage of weights of the constituents, etc., as follows:

	Constituents.	Average Volumes per cent.		Specific gravity.		Sum.	Weight per cent.	Weight, lbs. in 100 cu. ft. gas @ 70°.
H	Hydrogen,	45	×	0·0692	=	3·114	7·3171	0·23340
CH_4	Marsh gas,	36	×	0·559	=	20·124	47·2861	1·50835
C_2H_4	Olefiant gas,	8	×	0·981	=	7·840	18·4407	0·58823
CO	Carbonic oxide,	6	×	0·967	=	5·802	13·6331	0·43488
CO_2	Carbonic acid,	2	×	1·524	=	3·048	7·1620	0·22846
$4N+O$	Air,	2	×	1·000	=	2·000	4·6995	0·14995
H_2O	Vapor of water,	1	×	0·622	=	0·622	1·4615	0·04662
						42·558	100·0000	3·18985

The absolute temperature of the flame of marsh gas, computed by the same method used in the cases of hydrogen, carbon and carbonic oxide in the paper, is:

Marsh gas, $CH_4 = \frac{3}{4}C + \frac{1}{4}H = 13220° + 3085° = 16305°$.

[1] JOURNAL OF THE FRANKLIN INSTITUTE, for April, by Robt. Briggs, C. E.

AN IMPROVED FORM OF MARQUOI'S SCALE.

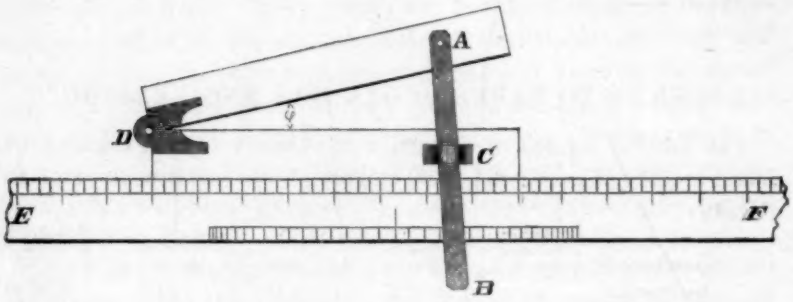
By Wm. D. Marks, Whitney Professor of Dynamical Engineering, University of Pennsylvania.

The attempt by one of the students in the Dynamical Engineering Department of the University, to invent some form of parallel ruler which would line shade cylindrical surfaces, led the writer, following out an idea suggested by Marquoi's Scales, to the invention shown in the accompanying sketch, and described below.

The instrument consists of the following parts (Fig. 1):

(1). A white wood straight edge two feet long, *EF*. On one edge it is divided into ¼ inch spaces. On the other edge a scale of versed-sines to a *radius* of 4 inches is laid off. Diameter, 8 inches.

Fig. 1.



(2). A pair of white wood rulers, *AD* and *CD*, each 8 inches long, hinged with an ordinary rule joint at *D*, and arranged so that they can be opened to any angle under 30°, and held there by means of a brass strip *AB*, able to turn about the pin at *A*, and sliding under the clamp at *C* with sufficient friction to be held at any point.

If we take any triangle, as *GHK* (Fig. 2), and laying its hypothenuse *GK* along a straight line GK_1, slide it along this line a distance as $GG_1 = KK_1$, we see that the new position G_1H_1 of the line

GH is distant from its former position a perpendicular distance $G_1L = GG_1$, sin HGK and parallel to it.

Let a = the required distance apart of the parallel lines.

Let m = the length of one division on the rule $EF = GG_1$.

Let φ = the angle HGK.

We have

$$a = m \sin \varphi.$$

$$\sin \varphi = \frac{a}{m}.$$

Fig. 2.

In the scale shown in Fig. 1, the upper edge of the straight edge has been divided into spaces of $\frac{1}{4}$ inch length.

To rule parallel lines $\frac{1}{8}$ of an inch apart, we must place the hinged rulers at an angle $\varphi = 30°$.

Thus,

$$\sin \varphi = \frac{\frac{1}{8}}{\frac{1}{4}} = \frac{1}{2}. \quad \text{Therefore, } \varphi = 30°.$$

For space $= \frac{1}{12}$	inch.	sin	$\varphi = \frac{4}{12} = \frac{1}{3}$.	Therefore	$\varphi =$	19°	28′
" " $\frac{1}{16}$	"	"	$\varphi = \frac{1}{4}$.	"	$\varphi =$	14°	29′
" " $\frac{1}{20}$	"	"	$\varphi = \frac{1}{5}$.	"	$\varphi =$	11°	33′
" " $\frac{1}{24}$	"	"	$\varphi = \frac{1}{6}$.	"	$\varphi =$	9°	36′
" " $\frac{1}{32}$	"	"	$\varphi = \frac{1}{8}$.	"	$\varphi =$	7°	11′
			etc., etc.				

Considering now the scale of versed sines, which is laid off along a diameter of 8 inches, for intervals of 5° of arc, and observing that the ratio of the distance between any two ruled lines to the length of a division on the rule = sin φ; we see that we have a means of altering the diameter of the cylinder to be shaded, and also the distance apart of the shade lines in any ratio we may desire. Thus, for a cylinder 1 inch in diameter we have the ratio

			$\frac{1}{8} = \sin \varphi$	and	$\varphi =$	7° 11′
For a $\frac{3}{4}$	inch	cylinder	$\frac{3}{32} = \sin \varphi$	"	$\varphi =$	5° 23′
" $\frac{1}{2}$	"	"	$\frac{1}{16} = \sin \varphi$	"	$\varphi =$	3° 35′
" $\frac{1}{4}$	"	"	$\frac{1}{32} = \sin \varphi$	"	$\varphi =$	1° 47′

For intermediate values φ can be accurately calculated or set by approximation, as desired.

The advantages derived from the use of this scale are:

(1). The reduction of error. Thus, an error of one one-hundredth of an inch on the scale in adjusting the rulers becomes, if the angle $\varphi = 7° 11'$, or $\sin \varphi = \frac{1}{8}$, one-eight-hundredth of an inch.

(2). An exquisite accuracy in spacing of cross-hatching, division of lines, or shading of cylindrical surfaces, otherwise only attainable by long and constant practice.

(3). The sight is greatly assisted, the divisions on the scale being so much larger than the distances between the lines.

PHILADELPHIA, *May* 3*d*, 1878.

THE METRIC SYSTEM.[1]

The committee, to whom was referred the communication and circular received from the Boston Society of Civil Engineers, asking the co-operation of the Club (*a*) to secure unanimity of action among the engineering professions, toward introducing the Metric System of Weights and Measures, and (*b*) to petition Congress for such legislation as may procure its universal adoption in the United States, respectfully begs to report:

That as the subject of the advantages of the several systems of weights and measures employed by different nations, has been so copiously considered during the past decade, by national and international conventions and by scientific societies throughout the world, your committee has not thought it advisable to discuss anew the merits of the several systems proposed, but have availed themselves of the existing literature and have based their report thereon.

First. They recognize in the Metric System of Weights and Measures the most desirable system of notation, either for theoretical computation or for measurements in the sciences and practical arts.

Second. They would heartily recommend the use of this system to all scientific and practical men; they advise its free introduction into all original literature bearing directly on professional work,

[1] Report of a Committee of the Engineers' Club, of Philadelphia, adopted April 6th, 1878.

recommending the conjoint use of the English notation with it, in order to familiarize the public with its practical utility, which, if accomplished, will constitute one of the most important means for its final and universal adoption.

Third. They would also recommend its gradual introduction into machine shops, and in all practical work wherever possible.

Fourth. They would request that, in all papers read before the Club, the Metric System be used conjointly with the English, and that on all maps, sections and drawings a metric scale be placed, for comparison with the ordinary mile, foot or inch scale.

Fifth. The committee deprecates the immediate compulsory adoption of the Metric System by State or National legislation, and considers that it would be a work of supererogation to attempt to compel any class of men, either technical or practical, to adopt it to their personal or pecuniary loss.

Sixth. They recognize the compulsory education of the children in our public schools in the Metric System, as one of the most important means toward its ultimate adoption, and would recommend to the state and municipal authorities throughout the United States, the enactment of such legislation as shall make the system familiar to the working classes.

Seventh. In conclusion, your committee heartily approves of the establishment and maintenance of the permanent International Bureau of Weights and Measures (*Bureau International de Poides et Mesures*), at Paris, with the object of promoting permanence, precision and uniformity in the standards, at the proportional expense of the contracting governments, and considers it of the highest importance that such appropriations should be made by Congress as shall secure for the United States a permanent representation.

Respectfully submitted by the committee:

RUDOLPH HERING, COLEMAN SELLERS, JR.,
WM. D. MARKS, HENRY C. LEWIS,
CHAS. A. ASHBURNER, *Chairman.*

New Explosive.—Nobel has invented an explosive which is still stronger than dynamite. From its resemblance to calf's foot jelly he calls it jelly powder. It is one great defect of dynamite that when it is damp the nitro-glycerine separates from the absorbing earth. The jelly powder, which consists of 94 or 95 per cent. of nitro-glycerine, and 5 or 6 per cent. collodion cotton, is so mixed as to assume a gelatinous form, which is tough, but can be easily cut with knives or shears, and applied to cartridges or balls. It is water-proof, acts in the same way as dynamite, but is at least 50 per cent. stronger.—*Forts. der Zeit.* C.

Glass from Slag.—The manufacture of glass from furnace slag has been brought to such perfection in England that the slag is taken directly from the furnace stack, so as to avoid the expense of re-melting, and reduce the cost of manufacture to the mere wages of the blowers and pressers.—*Forts. der Zeit.* C.

Death of Monsieur Lamy.—The death of M. Lamy, Professor in the Parisian Central School of Arts and Manufactures, and former Professor in the Faculty of Sciences at Lille, is announced by *Les Mondes.* After Crookes had discovered the green spectral ray, which is characteristic of thallium, and had shown that it belonged to none of the elements which were then known, Lamy was the first who succeeded in extracting the metal and describing its most important properties. C.

Solar Radiation.—M. J. Violle recommends the employment of a series of successive measurements, in the course of the same day, for determining the calorific intensity of solar radiations, and the loss of heat which the sun's rays experience in traversing our atmosphere. In 1875 he conducted a series of experiments on the summit of Mont Blanc, according to Pouillet's method of simultaneous observations at different heights, and in 1877 he made observations at Laghouat, in Algeria, according to his new method, at an altitude of 750 metres; and at Tagrait at an altitude of 993 metres. His results show the advantage of mountain observations, and he proposes a series of observations in order to determine more exactly the action of different agents of calorific absorption in the air. He considered the Algerian stations as peculiarly favorable on account of the uniformity of meteorological conditions, the air being very dry, and containing nearly the same quantity of vapor at every hour of the day.—*Comptes Rendus.* C.

Manganese Bronze.—Prof. Genti publishes an analysis of a specimen of manganese bronze from a Transylvania factory. It is nearly of the color of brass, is tenacious and ductile under the hammer, and contains sulphur, manganese, copper, zinc, iron, with traces of silica, tin, and carbon. The essential ingredients are 15 parts of copper, 4 of manganese, and 1 of zinc.—*Revue Indust.*

C.

Black Varnish for Copper or Wood.—In a large-mouthed bottle W. M. Ayres puts 500 grammes of methylated alcohol, and 90 to 100 grammes of pulverized gum lac. In another similar bottle he dissolves 90 to 100 grammes of powdered bitumen in 500 grammes of benzine. Shaking the bottles frequently, the solution is complete at the end of two or three days. The two solutions are mixed in equal proportions, and thickened to the consistency of cream with finely pulverized charcoal. It may be rendered more fluid, if required, by adding the proper quantity of a mixture of equal parts of alcohol and benzine.—*Soc. Franc. Photog.* C.

Rheostatic Machines.—Gaston Planté describes some of the peculiar characteristics of the action of his rheostatic machine. Among other experiments he sought to transform a certain quantity of dynamic electricity, and to ascertain the time necessary to exhaust the entire charge under the form of static effects. A secondary battery of 40 couples was charged during 15 seconds by two Bunsen elements, and then put in action upon the rheostatic machine. The apparatus was turned for more than a quarter of an hour in order to exhaust this charge in the illumination of a Geissler tube.—*Les Mondes.* C.

The Telephone as a Galvanoscope.—M. d'Arsondal has compared the telephone with the animal nerve, as an indicator of electricity, and states that the poorest telephone is at least a hundred times more sensitive than the nerve. In the silence of night he has heard the telephone vibrate when the induction coil was removed to a distance fifteen times greater than that of the minimum nervous excitation, indicating, according to the law of inverse squares, a sensibility more than 200 times greater. He regards the telephone as the best of all galvanoscopes, both for feeble electric variations, and for feeble continuous currents.—*Comptes Rendus.* C.

Eddies.—In Faye's communication to the French Academy on the movement of tempests, he referred to a memoir of M. Belgrand's upon the eddies of running water. In some subsequent remarks Belgrand stated that every modification of the bed of a river produces eddies which diminish the velocity of water. The phenomenon is so common as to attract little attention. The well-determined causes, which may give some idea of the movements of the atmosphere or of the erosion of valleys, he considered under three heads: 1. Eddies which bring the water from the middle towards the banks of a water course; 2. Eddies at bends; 3. Eddies at the junction of confluents. He illustrated his remarks by references to numerous geological results, especially along the banks of the Seine, the Marne, and the Yonne.—*Comptes Rendus.* C.

Fossil Coal Flora.—The *Annales des Mines* contains a summary covering fifty pages, of Grand' Eury's works upon the determination of the age of coal beds, by the aid of fossil flora. His first memoir was presented to the Academy of Sciences, and submitted to the examination of a commission, composed of MM. Daubrée, Tulasne, and Brongniart. M. Brongniart's report, which was inserted in the *Comptes Rendus* of August 12th, 1872, recommended the insertion of the memoir in full, in the *Memoires des Savants Étrangers*, which recommendation was adopted by the academy; but M. Grand' Eury continued and enlarged his work by new discoveries, so that it did not appear until 1877. Soon after it was published it received one of the gold medals from the general union of learned societies. While adopting most of the conclusions of Ginetz, Brongniart and Gruner, his systematic botanical and geological classifications and divisions have greatly enlarged our knowledge of the French carboniferous flora, and his work is one of the most valuable contributions to vegetable palæontology which has appeared for many years. C.

The Giffard Balloon.—The captive balloon for the Universal Exposition is nearly completed. It has a capacity of 25,000 cubic metres, and a diameter of 36 metres. The bag is made of alternate sheets of calico and caoutchouc, and is supposed to be impermeable to hydrogen. It will be inflated with pure hydrogen, prepared on the spot from iron filings and sulphuric acid. It will be able to raise fifty persons to a height of more than 500 metres.—*Les Mondes.* C.

Gas Motors for Tramways.—The Lenoir gas-engine has been improved by Otto, with a view to its employment on street railways. It is stated, as the result of several comparative trials, that the Harding steam-engine effects a saving of from 10 to 25 per cent. over horse-power; Mevarsky's compressed air-engine, a saving of from 33 to 37 per cent.; and the Otto gas-engine, a saving of from 61 to 67 per cent.—*La Gaceta Industrial.* C.

Transformation by the Simple Addition of Oxygen.—Demole has succeeded in transforming bromates of the ethylene series into bromides of the fatty series, by the simple agitation with oxygen in closed vessels. Dry oxygen and ethylene dibromate united with the liberation of heat; the product was not the oxide of ethylene dibromate, but the bromide of bromacetyle. Ethylene tribromate rapidly absorbs dry oxygen, and is changed into bromide of dibromacetyle. Berthelot compared these results to his own experiments upon the direct oxidation of free ethylene by chromic acid, with the formation of aldehyde. Propylene and camphene furnish, by the simple fixation of oxygen, propylic aldehydes and camphor.—*Comptes Rendus.* C.

Test of Woody Fibre.—Dr. Wiesner recommends phloroglucin as an extraordinarily delicate reagent for woody fibre. Place a drop of a half per cent. solution of phloroglucin upon a bit of pine, and moisten the spot with a drop of hydrochloric acid, and there immediately appears a beautiful lively red stain, verging upon violet. On drying, the violet tinge becomes still more marked. Even if the solution contains only one-hundredth of one per cent. of phloroglucin, the red color is very decided; and if there is not more than one-thousandth of one per cent., the reaction can be recognized, under proper precautions. If a strip of pine is allowed to remain in such a solution for twenty-four hours, hydrochloric acid gradually draws out a perceptibly reddish stain. The slightest traces of woody substance in vegetable tissues can be readily detected in this manner. The tenderest germs, by means of this reaction, show a woodiness in the cells. Every trace of woody substance in hemp and flax can be detected by the phloroglucin. Dr. Wiesner suggests that it may be used to distinguish hemp from flax, and also as a means of dyeing fabrics woven from vegetable fibres.—*Dingler's Polytech. Jour.* C.

Rock-Cleavage.—Daubrée has extended his studies of molecular mechanics to various features of geological structure. In the geometrical regularity which is observable in fractures produced by torsion, and slipping or shearing, he finds close analogies to the various joints, faults, schists, and minor cleavages which pervade the earth's crust.—*Comptes Rendus.* C.

Transverse Vibrations of Liquids.—M. P. Dubois has conducted some experiments upon sand, in Jamin's laboratory, substituting a liquid for sand as a means of making nodal divisions. Tinging water with vermilion, he obtains clearly marked equidistant stains, which furnish simple and satisfactory demonstrations of important acoustic laws.—*Comptes Rendus.* C.

Instantaneous Action in the Telephone.—Du Moncel attributes the vibrations of the magnetic nucleus in the telephone to the contractions and dilations of the magnetic molecules, and thinks his hypothesis is confirmed by the modifications that have been observed in the length of a bar of iron, when subjected to powerful magnetic action. The greater efficacy of induced currents in telephonic transmissions, he believes to be due to their instantaneousness, thus introducing an element like that which La Place found in the action of gravity. According to the researches of De la Rue, the currents produced by the vibrations of the voice, in ordinary telephones, represent, in intensity, those of a Daniell element, traversing a resistance of a hundred megohms, or ten million kilometres of telegraphic wire of four millimetres diameter.—*Comptes Rendus.* C.

Phosphorescence and Fluorescence.—Favé attributes both of these phenomena to "the reciprocal action of material vibrations and æthereal waves." Even ordinary phosphorus shines in a vacuum, in nitrogen, and in hydrogen, when there is no evidence of any chemical action. But when the phosphoric vapor reaches a certain density this light ceases. This furnishes one of the simplest examples of a vapor absorbing the waves which are produced by the same body when in a solid state. Such an extension of Kirchhoff's law to solid bodies is confirmed by the nitrate of uranium, which gives eight brilliant phosphorescent lines, each corresponding to an absorption line, when a spectrum is made to traverse the salt.—*Comptes Rendus.* C.

A Deep Well.—The artesian well in Pesth is one of the deepest borings of modern times. It has already reached a depth of 951 metres, while the Parisian well, at Passy, is only 547 metres deep. The water is pure as crystal, rich in calcium and baryta, having a temperature of 37° C., and flowing 6940 hectolitres per day. It is intended to sink the well until the water reaches a temperature of 65°, and flows in sufficient quantity to supply the baths and the city offices with hot water.—*Berg- u. Huett Zeit.* C.

Elastic Forces of Mixed Vapors.—DuClaux finds that aqueous solutions of monatomic alcohols obey, in their distillation, the law $\frac{\alpha}{\varepsilon} = m\frac{a}{a+e}$; a and e being the volumes of alcohol and of water in the heated liquid, α and ε the same volumes in the products of distillation. The aqueous solutions of formic and acetic acids obey, in their distillation, the law $\frac{\alpha}{\varepsilon} = m\frac{a}{e}$, in which α and a represent for the acid what they have previously represented for the alcohol. From these laws he is able to calculate the individual tensions of the vapors in the mixture, the boiling temperature in a liquid of known composition, and other important details.—*Comptes Rendus.* C.

Solar Magnetism.—Tacchini states that among the substances which correspond to the luminous rays in the solar spectrum at the base of the chromosphere, iron predominates enormously. Its vapors are the most generally diffused, and the most constant, upon the sun's surface. Next to iron comes magnesium, although its atomic weight is considerably less. Other substances are comparatively rare, and they disappear almost entirely at the epoch of minima of solar spots. He thinks that these facts may serve to explain the parallelism between the variation curves of sun spots and of terrestrial magnetism.—*Comptes Rendus.* C.

Ice-Making.—Toselli has addressed a note to the French Academy on the improvements which he has introduced into machines for making ice. He is now able to obtain blocks weighing from one to five kilogrammes, in two minutes. Pictet & Co. state that their machines produce ice at a cost of one centime per kilogramme. There are thirty-seven of their machines now in operation, some of which are employed by the English skating rinks. C.

Nettle Cloth.—At Langenschwalbach, Prussia, some interesting experiments have been made with the fibre of the common nettle. When treated in the same way as hemp, the fibres were as fine as silk and as strong as linen. The result of the first experiments was so encouraging, that a large plantation of nettles has been made, in order to test the manufacture on an extensive scale.—*Les Mondes.*

C.

Launch of the Steamship State of California.—This vessel, built for the Pacific Coast Steamship Co., of San Francisco, to run between that city and Portland, Oregon, was launched from the shipyard of Messrs. Wm. Cramp & Sons, in this city, on May 16th. So complete were the arrangements that at precisely 1 o'clock P. M., the hour named for the launch, the shoes were cut through, and she started without assistance, and slid quietly into the water without a hitch or jar of any kind.

This vessel is a full three-decked iron steamer, 320 feet long, 38 feet breadth of beam, and 28 feet depth of hold, built under the rules of the British Lloyds for the highest rating.

She will have compound surface-condensing engines, with direct-acting inverted cylinders of 51 inch stroke, the high pressure cylinder being 42 inches diameter, and the low pressure cylinder 73 inches; the engine to develop 1700 horse power. Steam will be furnished by 6 internally fired, return tubular boilers, 10 feet 3 inches long, and containing 6300 square feet of heating surface. Each boiler has 42¼ square feet of grate area.

The propeller is a true screw, 16 feet diameter and 25 feet pitch, and is expected to make 64 revolutions per minute.

She will be fitted with cabin accommodation for 200 first-class passengers, principally under the main deck, and also for 200 steerage passengers. The dining saloon, located amidships, is 40 feet long, and the full width of the vessel, and the Social Hall, of the same dimensions, is located at the upper deck, both elaborately finished in hard woods.

The State of California is to be brig rigged; will be amply supplied with boats and other life-saving apparatus for her full complement of passengers and crew; will be fitted with steam steering gear, and all the latest improvements in marine architecture, and is expected to attain a speed of 15 knots per hour on a consumption of 35 tons of coal per day.

Book Notices.

CHEMICAL EXPERIMENTATION: Being a handbook of lecture experiments in inorganic chemistry. By Samuel P. Sadtler, A. M., Ph. D., Assistant Professor of Chemistry in the University of Pennsylvania. John P. Morton & Co., publishers, Louisville.

As remarked by the author in his preface, "the exact end and aim of the present work may be readily understood from the title, and by turning over a few pages of the book. It is a handbook, and not a text-book, in any sense whatever."

Chemical literature has long been deficient in just such a work as Prof. Sadtler has produced. Every lecturer and teacher of chemistry has felt the need of a *systematically* arranged manual to guide him in his demonstrations. Following the arrangement of the modern text-books on chemistry, the handbook of lecture experiments gives detailed descriptions of the most approved methods of demonstration. Most of the experiments are illustrated by the forms of apparatus. The cost and trouble of illustration are nowhere better paid for, than in such a work as this; this fact Prof. Sadtler has happily recognized.

The appendix on "Chemical Manipulation" contains sound and practical advice to those who are not familiar with the *tools of the trade*, and the way of using them. Tables of the metric system, and the value of the same in English weights and measures, and a comparison of Centigrade and Fahrenheit degrees, are useful and convenient addenda. A copious index, permitting any experiment to be referred to, gives additional value to the work.

Teachers, and amateurs in chemistry, will find Prof. Sadtler's handbook a help which they would be unwilling to dispense with, after once learning its value.

The publishers deserve great credit for the style in which the work has been executed; nothing better could be desired. B.

NEW ENCYCLOPEDIA OF CHEMISTRY. Lippincott & Co., Philadelphia. Parts XXVI to XXX now issued. To be completed in 40 parts, at 50 cents each.

The subject Iodine is finished in the first of the present numbers; the last takes up Oils. The great progress made in science and the arts since the work of Dr. Muspratt was laid before the public, has necessitated important changes in a work constructed on a like basis. Many details of value twenty years ago have now only a historical interest. To eliminate or condense in a work like this, requires ex-

perience and sound judgment. In the numbers before us this difficult task appears to have been performed with discretion.

The extended article on Nitro-Glycerine, and the explosive compounds into the composition of which it enters, and the applications of the same, may be remarked upon as evidencing the progress of chemical discovery since the publication of the work of Dr. Muspratt, which does not mention the subject.

The "New Encyclopedia" will fill a wide gap of twenty years with those having Dr. Muspratt's work, and who desire to bring the subject of chemistry in its application to the arts and manufactures down to the present time. B.

Franklin Institute.

HALL OF THE INSTITUTE, May 15th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the Vice-President, J. E. Mitchell, in the chair.

There were present 110 members and 34 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 6 persons were elected members of the Institute; and the following donations to the Library were reported:

Phonographic Instructor, by Jas. C. Booth. Philad'a, 1849.

Catalogue of Wool Manufactures, 38th Exhibition of American Institute. N. Y., 1869.

Catalogue of Paintings, Drawings, Statuary, etc., Phila. Central Fair.

Rules of 43d Exhibition of American Institute. N. Y., 1874.

Charter and By-Laws of the Franklin Institute. Phila., 1864.

Annual report of the Hartford Steam Boiler Inspection and Insurance Co. 1873.

Proceedings of the National Convention of United States' export trade, held in Washington, 1878.

Annual report of the Chief Engineer of the Water Department of the city of Phila., 1862, 1864 and 1874. From John H. Cooper.

Appendix R. R. of annual report of the Chief of Engineers for 1877, by E. H. Ruffner. Wash., 1877.
From Reading Society Natural Sciences.

Annual report of the Committee of Management of Steam Users' Asso. to the members. 1877. From the Asso.

Transactions of the Literary and Historical Society of Quebec. Sessions 1865-6 and 1867-9. Quebec. From the Society.

Forest Culture and Eucalyptus Trees, by E. Cooper. San Francisco, 1876. From H. J. Smith, Phila.

Patents and the useful Arts, by H. Howson. From the Author.

Results of the Washington Observations, 1853 to 1860. U. S. Naval Observatory. From the Observatory, through Prof. J. S. Nourse.

Fifth annual report of the New Jersey State Board of Agriculture for 1877. Trenton.

Geological Survey of New Jersey. Annual report of the State Geologist for the year 1877. From the State Board.

Publications of the Cincinnati Observatory, Nos. 2, 3 and 4. From O. Stone, Director.

Statistique international des Mines et Usines publiée par la Comité Central de Statistique de Russée et redigée, par Jean Bock. Part 1. St. Petersburg, 1877. From E. Young, U. S. Official Delegate to International Statistical Congress.

Twenty-sixth annual report of the Board of Water Commissioners to Common Council of the city of Detroit for the year 1877. Detroit, 1878. From F. D. Henry, Chief Engineer.

Die Culur-Flora der Ostrauer und Waldenburger schichten von D. Stur. Wien, 1877. From K. K. Geologischen Reichsanstalt.

Catalogue of the special loan collection of Scientific Apparatus at the South Kensington Museum, 1876. 3d Edition. London, 1877. From D. S. Holman.

Minutes of Proceedings of Institution of Civil Engineers, Vol. 51, Sess. 1877-78. Part 1. London, 1878. From the Institution.

Annual report of the Lighthouse Board to the Secretary of the Treasury for the year 1877. Wash. From the Lighthouse Board.

The Secretary reported that the Committee on Science and the Arts, at its meeting held on the 1st inst., recommended the award of the Elliott Cresson medal to Henry Bower, for having first introduced into the United States the manufacture of pure inodorous glycerine.

Mr. H. P. M. Birkinbine read the paper announced for the evening, being the second one on the Future Water-Supply of Philadelphia.[1]

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[1] Mr. Birkinbine's first paper was printed in the JOURNAL for May, and this one will appear in the July number.

Mr. Hector Orr presented a verbal communication upon silk culture in the United States.

The Secretary's Report embraced Kennedy's Spring Piston for pumps, and Applegate's Electric Door Mat Alarm.

Mr. Solomon W. Roberts presented the following preamble and resolutions, which on motion were unanimously adopted:

In Memory of Joseph Henry.

Whereas, The Franklin Institute, of the State of Pennsylvania, for the promotion of the mechanic arts, desires to express and to record upon its minutes, its deep sense of the great loss caused by the death of Professor Joseph Henry, the Secretary of the Smithsonian Institution, who died at Washington on Monday last, May 13th, 1875, in the 81st year of his age,

Resolved, 1. That in the long list of names of men eminent for their talents, their acquirements, and their usefulness, who have taken an active part in promoting the objects of the Franklin Institute, since it was established more than fifty years ago, no name shines with a brighter lustre than that of Joseph Henry.

2. That his valuable services as a member of the Committee on Science and the Arts, and his contributions to the Journal of the Institute, attest the lively interest which he took in the welfare of this institution.

3. That his career as an apprentice boy; the teacher of a school; the professor in a college; the discoverer of new truths, and the inventor of new improvements in the sciences of electricity and magnetism, and their applications to the uses of mankind, in the electric telegraph and otherwise;—as well as his services in the Smithsonian Institution; and as the founder of the Signal Service system, and the great improver of the lighthouses on the coast; will cause his name to be remembered and classed with that of Benjamin Franklin, after whom this Institute is named.

4. That the name of Joseph Henry is worthy to be honored, not only for his abilities, but also for his character; for his industry; his probity; his economical habits; his eminent trustworthiness; and his kind-hearted urbanity; and the Franklin Institute desires to unite with the scientific societies, not only of this country, but also of the world, in deploring his loss and in honoring his memory.

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*